PB-240 567

AIR POLLUTION: ASSESSMENT OF AIR QUALITY IN ST. LOUIS, MISSOURI, UNITED STATES. APPENDIX B

NATO Committee on the Challenges of Modern Society

Prepared for:

Environmental Protection Agency

April 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	PB 240 567

4. Title and Subtitle

Air Pollution, Appendix B - Assessment of Air Quality in St. Louis, Missouri, United States.

5. Report Date: April 1973

6.

7. Author(s)

8. Performing Organization Rept. No. 6

9. Performing Organization Name and Address

NATO Committee on the Challenges of Modern Society, 1110 Bruxelles, Brussels, Belgium

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Office of Air and Waste Management, Environmental Protection Agency, Washington, D. C. 20460

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

17. Key Words and Document Analysis. 17a. Descriptors

air pollution
air quality
St. Louis, Missouri

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

Reproduced by
NATIONAL TECHNICAL INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Available from NTIS	UNCLASSIFIED	103
	20. Security Class (This Page) UNCLASSIFIED	22. Price PC 5.25 / 2.25

ASSESSMENT OF AIR QUALITY IN ST. LOUIS, MISSOURI, UNITED STATES

Published as Appendix B to the NATO/CCMS Air Pollution Publication, "Guidelines to Assessment of Air Quality (Revised) SOx, TSP, CO, HC, NOx and Oxidants"

April 1973

OTHER NATO/CCMS AIR POLLUTION PUBLICATIONS

Technical Report of the Conference on Low Pollution Power Systems Development, N.4

Proceedings of the Second Meeting of the Expert Panel on Air Pollution Modeling, N.5

Guidelines to Assessment of Air Quality (Revised) SO_x, TSP, CO, HC, NO_x and Oxidants, N.6*

Appendix D - Assessment of Air Quality in Oslo, Norway

Air Quality Criteria for Sulfur Oxides, N.7*

Air Quality Criteria for Particulate Matter, N.8*

Air Quality Criteria for Carbon Monoxide, N.10*

Proceedings of the Third Meeting of the Expert Panel on Air Pollution Modeling, N.14

Air Quality Criteria for Nitrogen Oxides, N.15*

*Also available in French

These documents many be obtained from the NATO Committee on the Challenges of Modern Society, 1110 Bruxelles, Brussels, Belgium, or from the Air Pollution Technical Information Center, Office of Air and Water Programs, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, U.S.A. (English only).

ASSESSMENT OF AIR QUALITY IN ST. LOUIS, MISSOURI, UNITED STATES

INTRODUCTION 1

DESCRIPTION OF STUDY AREA 3

I. Population and Jurisdictions 3

II. Topography and Climatology 3

III. Industry 7

IV. Current Pollution Control Activities 9

SOURCES AND EMISSIONS 13

I. Introduction 13

II. Inventory Procedure 14

A. Fuel Combustion in Stationary Sources 14

B. Fuel Combustion in Mobile Sources 16

C. Solid Wastes 18

D. Industrial Processes 19

III. Results 19

A. Stationary Fuel Combustion 21

B. Mobile Fuel Combustion 29

C. Refuse Disposal 29

D. Industrial Processes 32

AIR QUALITY MONITORING 34

I. Introduction 34

II. Monitoring Network 35

III. Results 39

A. Initial Assessment of SO_2 and TSP 39

B. SO_x and TSP Data Collected Since Initial Assessment 45

C. Phase II Pollutants 52

METEOROLOGICAL MEASUREMENTS 58

I. Introduction 58

II. Average Meteorological Conditions 59

A. Wind Flow 59

B. Mixing Height 59

C. Relative Frequency of Wind Speed, Direction and Stability 61

D. Temperature 61

III. Comparison with Meteorological Measurements of Winter 1970/1971 62

PROJECTIONS OF EMISSIONS 65

I. Introduction 65

II. Expected Growth and Development 66

III. Procedure for Calculating Emissions 69

IV. Results 72

AIR QUALITY MODELING 83

I. Introduction 83

II. Procedure 83

III. Results 86

A. Sulfur Oxides 87

B. Particulate Matter 87

INTRODUCTION

The Air Pollution Pilot Study of the NATO Committee on the Challenges of Modern Society (CCMS) designed a program to demonstrate and encourage the development of long-range air quality management programs. The document, "Guidelines to Assessment of Air Quality (Revised) SO_x, TSP, CO, HC, NO_x, and Oxidants,* was written to provide a common basis to utilize the systems approach in the development of these programs.

To demonstrate the application of these techniques to different situations, a series of actual assessment studies was undertaken. Initially, case studies were carried out by the pilot (U.S.) and the co-pilots (Germany and Turkey) in three locations--Ankara, Turkey; Frankfurt, Germany; and St. Louis, United States. Since the inception of the Project, assessment studies are under way or planned in Oslo, Norway; Milan and Turin, Italy; and Rotterdam, The Netherlands. The results of these studies (published as appendices to the guidelines document) will serve to illustrate the techniques that can be used and will greatly enhance the data base and experience for Nations wishing to develop similar programs. This report describes the air pollution assessment study in St. Louis, United States.

The St. Louis metropolitan area was chosen as a site for a

---

* SO_x is sulfur oxides; TSP is total suspended particulates; CO is carbon monoxide; HC is hydrocarbons; and NO_x is nitrogen oxides.

case study because of the possibility to investigate the aspects of air pollution assessment in a multi-jurisdictional area. The St. Louis metropolitan area transcends two States and includes a number of local air pollution control programs. The St. Louis region also provides an opportunity to illustrate the assessment procedures for an area containing a wide variety of industry and a large automobile population.

This report includes the assessment of sulfur oxide and particulate pollution (Phase I) and the assessment of carbon monoxide, nitrogen oxides, hydrocarbon, and oxidant pollution (Phase II). Phase I of the study was conducted during the fall and winter of 1970-1971 and was reported as an appendix to the November 1971 issue of the Guidelines document. Phase II of the study was conducted during 1972.

It is important to note that the assessment and control of pollution in the St. Louis area has been a continuing operation for many years. Thus, historical data and the mechanisms for the collection of additional data were already available for the NATO/CCMS study. The primary effort, therefore, in the St. Louis case study was to bring together and update, if necessary, all the information required for an assessment project. The availability of this data base allowed refinements that would not have been otherwise possible.

DESCRIPTION OF STUDY AREA

I. Population and Jurisdictions

The study area, as presented in Figure 1, consists of the City of St. Louis and seven surrounding counties--St. Louis, St. Charles, Franklin, and Jefferson Counties in Missouri, and Madison, St. Clair and Monore Counties in Illinois. This area occupies 11,850 square kilometers and contained a 1970 population of 2,359,380 which represents an 11.3 percent increase over 1960. Table 1 gives population and economic statistics for the jurisdictions included within the study area for 1960 and 1970. Figure 2 gives the population density of the study area on a grid-by-grid basis.

II. Topography and Climatology

St. Louis is situated on a gently rolling terrain with gradual undulations rather than sharply defined ridges and valleys. Although there are a few rises and drops of 30 meters in elevation over a short distance, the area within a 40 kilometer radius of downtown St. Louis is practically free of major orographic features that would strongly influence meteorological variables. Elevations range from 146 meters above sea level in the downtown St. Louis area to about 170 meters at Lambert Field, 20 kilometers northwest of the downtown area, with a slight ridge rising to 180 meters in between. A flat area known as the American Bottoms, surrounded by a crescent-shaped bluff rising

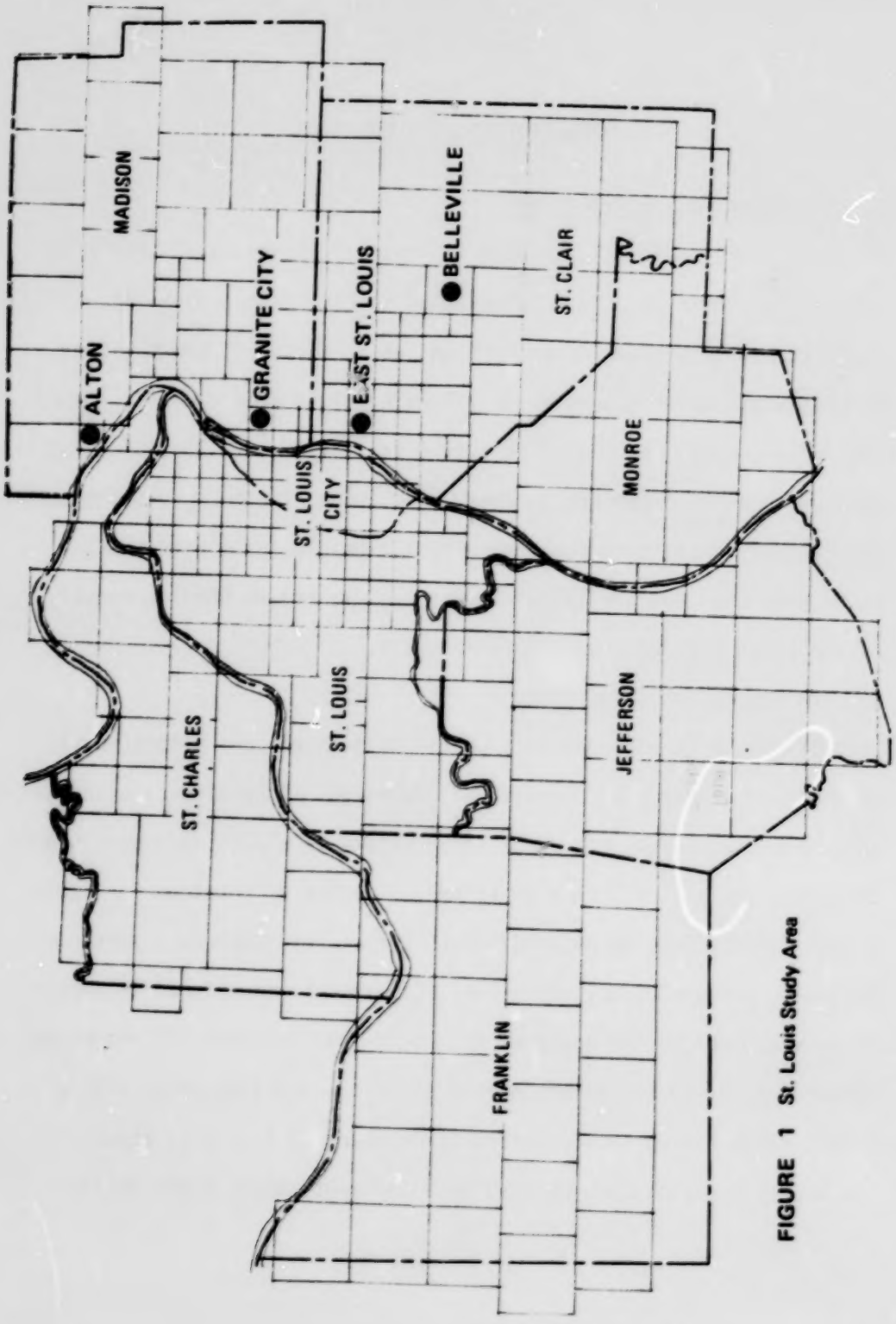


FIGURE 1 St. Louis Study Area

TABLE 1

ECONOMIC AND POPULATION DATA FOR ST. LOUIS STUDY AREA

	Value Added by Mfg. (1963, $1,000) †	Total Mfg. Employees (1963) †	No. of Mfgs. of Non-Durable Goods, 20 Employees or More, 1963 *	No. of Mfgs. of Durable Goods, 20 Employees or More, 1963 **	1960 Population	1970 Population	Percent Change 1960 - 70
Missouri							
Franklin Co.	40,029	4,842	20	14	44,566	54,452	22.2 %
Jefferson Co.	44,333	3,488	8	5	66,377	103,677	56.2 %
St. Charles Co.	23,034	2,079	8	4	52,970	92,651	74.9 %
St. Louis Co.	838,758	68,110	62	154	703,532	956,196	35.9 %
St. Louis City	1,476,939	129,069	448	339	750,026	607,718	– 19.0 %
Illinois							
Madison Co.	459,710	33,655	38	41	224,689	246,126	9.5 %
Monroe Co.	998	113	1	0	15,507	18,959	22.3 %
St. Clair Co.	236,460	18,443	51	39	262,509	279,601	6.5 %
	3,120,261	259,799	636	596	2,120,176	2,359,380	11.3 %

* includes food, tobacco, textiles, apparel, leather, paper, printing, chemicals, petroleum, rubber, and plastics.

** includes lumber, wood products, furniture, stone, clay, glass, primary and intermediate metal, electrical and non-electrical machinery, transportation, ordnance, instruments, and miscellaneous products. . .

† U. S. Bureau of Census, City - County Data Book, 1967.

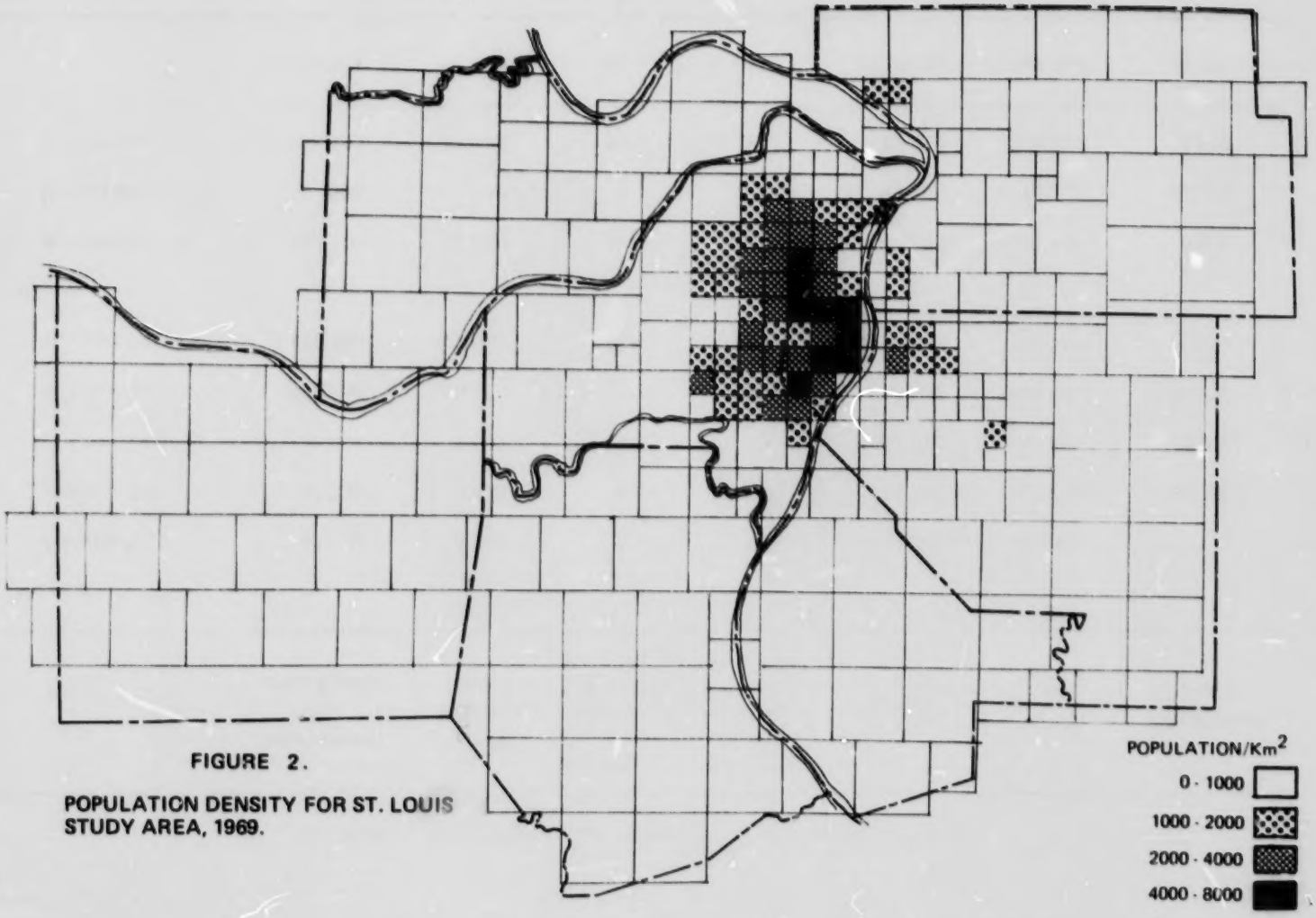


FIGURE 2.

POPULATION DENSITY FOR ST. LOUIS STUDY AREA, 1969.

to an average of 195 meters above sea level, lies on the east side of the Mississippi River across from St. Louis. The boundary bluff extends from Alton, Illinois, on the north, passes 16 kilometers east of the Mississippi at East St. Louis, and returns to within 5 kilometers of the Mississippi opposite the mouth of the River des Peres on the south. The average elevation of the Mississippi River is 122 meters above sea level, and of the American Bottoms 128 meters above sea level, about 18 meters below the main commercial area of St. Louis. The Springfield and Decatur metropolitan areas are located approximately 80 kilometers northeast of the study area. There are no other large industrial or populated areas within a radius of 160 kilometers.

The St. Louis area experiences meteorological conditions typical of most Great Plains cities that are not influenced by major natural features such as mountains or large bodies of water. Winters are fairly brisk and stimulating as a rule but seldom severe. Almost every winter has several periods of mild weather and occasional short spells of extreme cold. Summers are generally warm, and spring and fall are characterized by moderate temperatures. Marked variations in day-to-day conditions are provided by changes from warm, moist air flowing up from the Gulf of Mexico during some periods to cool, dry air from the Northern Plains during others.

III. Industry

Figure 3 gives an indication of relative industrial land use in the core of the metropolitan St. Louis Area. Table 1 lists major

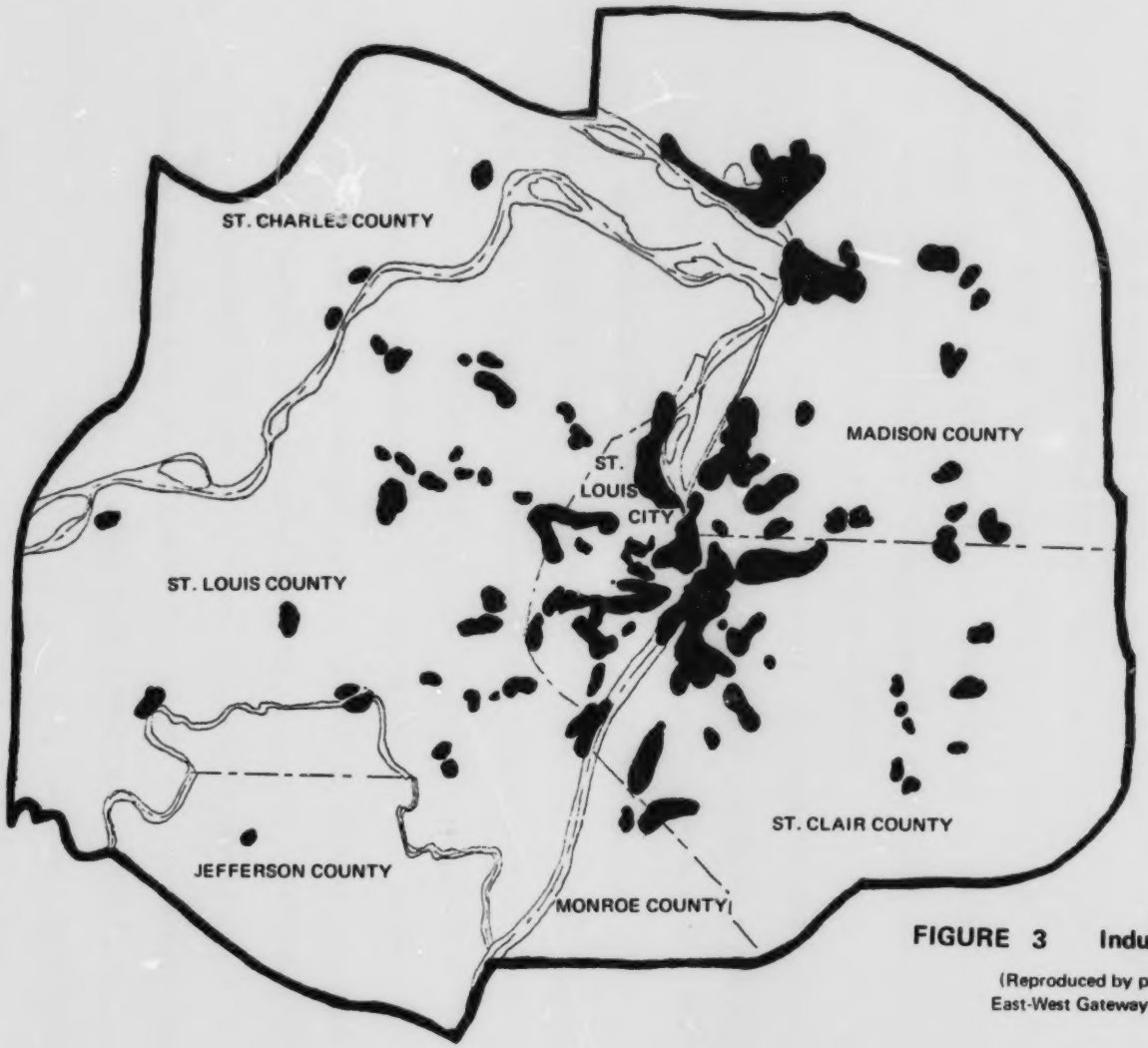


FIGURE 3 Industrial Land Use

(Reproduced by permission of the
East-West Gateway Coordinating Council)

manufacturing parameters for the study area. The largest industry in terms of employment is the manufacture of transportation equipment, employing over 20 percent of the total manufacturing employees. This category includes automobile assembly, aircraft, truck and bus body plants and has over 70 establishments. Primary metal (iron and steel), food and kindred products are the next largest industries, each employing about 8-9 percent of the total manufacturing employees, although the latter has about three times the number of establishments as the primary metal industries (300 vs. 100). Other industries employing over 6 percent of total manufacturing employees each include chemical and allied products, fabricated metal products, machinery (except electrical), and electrical equipment. Printing and publishing have the largest number of establishments, over 450, while employing less than 5 percent of the total manufacturing employees.

IV. Current Pollution Control Activities

There are three operating programs for the prevention and control of air pollution in the Missouri portion of the St. Louis Interstate Air Quality Control Region.* They are the City of St. Louis Air Pollution Control Division, Department of Public Safety; the Air Pollution Control Division, St. Louis County Health Department; and the Missouri Air Conservation Commission in the remaining areas of the regions. The Missouri Air Conservation Commission by state statute is the agency responsible for the prevention and control

* The entirety of the U.S. is sub-divided into areas called Air Quality Control Regions (A.Q.C.R.'s). The Metropolitan St. Louis A.Q.C.R. consists of the study area and four additional counties in Illinois.

of air pollution in the State of Missouri.

The Commission is authorized to promulgate rules and regulations for air pollution control and may grant exemptions to local control agencies which as a minimum have regulations at least as stringent as the state. The City of St. Louis and St. Louis County have had exemptions since 1967 and are the agencies responsible for air pollution control in their areas of jurisdiction. The Commission and the two local agencies work closely to provide enforcement of existing regulations and in developing new regulations for the prevention and control af air pollution for the St. Louis area. Pollution monitoring activities are carried out primarily by city and county agencies.

Legal counsel for the Missouri Air Conservation Commission is provided by the state attorney general and one assistant assigned half time. This assistant attorney general attends all public hearings on proposed regulations and hearings on variance applications. The city is provided legal counsel by a city attorney while the county attorney provides legal assistance to the St. Louis County Health Department. Rules and regulations are passed in the form of ordinances by the legislative bodies of St. Louis and St. Louis County. Enforcement in the city and county is provided by teams of inspectors who are authorized to issue violation citations. Visible emission regulations affecting automotive sources are enforced by the city and county police. The state has proposed visible emission regulations for automotive sources and the state police are expected to enforce these regulations when adopted.

Stationary source control regulations are included in the city and county ordinances. The Missouri Air Conservation Commission has adopted rules and regulations for stationary sources for the St. Louis area. Enforcement by the state is by periodic inspections and in response to complaints. The state police have been enlisted to assist in detecting open burning violations during the night-time hours. The Air Conservation Commission plans to establish a field office in the St. Louis area. The purpose of this office will be to provide better enforcement of the state law in the remainder of the region.

The Division of Air Pollution Control of the Illinois Environmental Protection Agency has the responsibility for controlling air pollution in all portions of Illinois. They use various air pollution control agencies to complement their activities in areas where such agencies are available. There are projected state-wide regulations for particulates and new state regulations will be promulgated for sulfur dioxide, nitrogen oxides, hydrocarbons, carbon monoxide and photochemical oxidants.

Surveillance of atmospheric emissions and air quality monitoring for the Illinois portion of the St. Louis metropolitan air quality control regions is carried out by the Illinois Environmental Protection Agency regional office in Collinsville. This regional office serves exclusively the St. Louis region. The Granite City air pollution control agency provides routine surveillance, complaint investigations and air monitoring for its area in cooperation with Illinois' program. Preparatory work in enforcement cases is usually

performed by the regional office. Requests for permits and variances are processed through the headquarters in Springfield.

SOURCES AND EMISSIONS

I. Introduction

The emission inventory serves as a means to quantitatively assess the emissions of air pollutants in a designated area. It provides one of the basic ingredients in the data base upon which an air resources management plan is structured. For the St. Louis area, an emission inventory was prepared using the data provided by the appropriate State and local agencies. Emission estimates were made for the five primary pollutants--particulate matter, oxides of sulfur, carbon monoxide, oxides of nitrogen, and hydrocarbons. Emissions were estimated individually for each of the point sources and collectively for the multitude of area sources. Emissions were calculated on an annual basis and extrapolated to show seasonal variations. Sources of emission were identified geographically through the use of a grid coordinate system.

Emissions were estimated by the use of various indicators, such as fuel consumption, refuse burning rates, vehicle kilometers, production data, and emission factors that relate these indicators to emission rates. The factors represent average emission rates for a particular source category. They have been developed by either source sampling or process material balances. Since inherent differences among individual sources cannot always be considered,

discrepancies between the estimated and actual emissions are more likely with individual sources than with the total emissions for a source category. In general, the data presented here are approximate and may be partial totals due to the lack of information on some sources. The estimates are of sufficient accuracy, however, to identify the extent and distribution of air pollutant emissions in the St. Louis study area.

II. Inventory Procedure

The St. Louis emission inventory was prepared for this study by updating and revising existing inventories prepared by local air pollution control agencies. The emission inventory is representative of the year 1969. The sources of pollution were grouped into five categories: (1) stationary fuel combustion; (2) transportation; (3) refuse disposal: (4) industrial processes; and (5) evaporative losses. These categories were further divided into point and area sources as appropriate.

One hundred and eleven large sources were selected as point sources. These were inventoried individually and were located precisely on the grid coordinate system. All other sources were considered as area sources. Their emissions were calculated jointly by source category with the emissions being distributed to the various grids using population, industrial development, and traffic information as basis. The information sought and the techniques used in estimating emissions are summarized in this section of the report.

A. Fuel Combustion in Stationary Sources. The quantities of

each type of fuel used in the St. Louis area were to be determined and assigned geographically. The following is a step-by-step procedure by which this was accomplished.

1. The total quantity and average quality of the fuels used in the study area were determined according to consumer category (residential, industrial, etc.).

2. The amounts of the different fuels used by each point source were determined individually and assigned to exact locations.

3. The amount of each fuel used by area sources was obtained by difference.

4. The fuels used by the area sources were distributed among the grids primarily on a population density basis for residential heating and for industrial sources by use of land-use data.

Data on fuel usage in point sources was obtained from each source by the local air pollution control agencies. In addition, they had estimated total fuel use for source categories by contacting the gas companies and fuel oil dealers in their jurisdictions. An estimate of coal consumption by area sources was derived from historical information on the number of coal boilers in use and then applying an average quantity of coal consumed per boiler which is dependent on the number of degree days for the year.

The large fuel consumers in the St. Louis area are steam-electric generating plants, oil refineries, coking ovens, and cement plants. Combined, these sources consume over 80 percent of the total

coal burned in the area. The determination of where the remainder of the fuels are burned was approximated by assuming that those used by residential and commercial sources are proportional to population density. Likewise, industrial fuels were apportioned into grids of concentrated industrial activity by means of land-use maps.

Several indicators were used to determine seasonal variation in fuels use. The ambient temperature was used to calculate variations in the consumption of fuels for space heating. The demand for electrictiy provided the basis for calculating the seasonal variation in emissions from power plants. The demand for electricity is highest in the summer months when air conditioning is utilized, followed closely by the winter season when more lighting and heating are required. Fuel usage for process heating was assumed constant since this use is generally independent of seasons.

B. Fuel Combustion in Mobile Sources. Information on fuels use by mobile sources was obtained from the various agencies and gasoline companies. This category included motor vehicles, locomotives, vessels, and aircraft.

The emissions from motor vehicles are estimated by applying average emission factors (grams per kilometer) to the data on motor vehicle travel in the area (vehicle-kilometers per grid). The emission factors are dependent on vehicle characteristics and average travel speed. The motor vehicle travel data used in calculating motor vehicle emissions were sub-corridor vehicle-mile data for most

of the area and traffic counts for the remainder. These data, resulting from a comprehensive transportation study, were supplied by the East-West Gateway Coordinating Council. Because of the availability for the St. Louis area of very detailed traffic data in the form of maps, the procedure of determining vehicle miles of travel per grid consisted simply of transposing the grid system onto the traffic map and extracting the required data. Therefore, the reliance on the less precise estimation techniques such as fuel sales was not necessary.

Emission factors for light duty vehicles are constantly being refined and updated because of ever-changing vehicle population and improvements in measurement technology. The emission factors used in this study were derived primarily from a recent study of light-duty vehicles in six U.S. cities. Factors derived from this study should be directly applicable to St. Louis as this was one of the six cities in the study.

Information on vehicle characteristics (distribution of vehicles by weight, age, and manufacturer) was not readily available for St. Louis; however, such statistics were available for a similar area. Although very good information was available on vehicle travel, such was not the case with respect to travel speeds. The traffic information supplied by the East-West Gateway Coordinating Council coupled with numerous assumptions formed the basis for estimating the average speed within each grid. The available

information allowed the classification of grids according to only two speed ranges, e.g., 20 mi/hr. (32 km/hr.) and 40-45 mi/hr. (64-72 km/hr.).

The estimation of emissions from the operation of aircraft requires information on the volume of air traffic activity in the area. The basic information required is the number of aircraft take-offs and landings in the area classified by type of aircraft. For the municipal airport (Lambert Field), these data were supplied by the Federal Aviation Administration.

There are approximately 10 major railroads operating in the St. Louis metropolitan area. To obtain an estimate of the emissions of pollutants from this activity, each of the railroad companies was asked to provide information on the quantity of fuel consumed by trains while operating within the boundaries of the study area. These fuels were then apportioned to grids on the basis of track length in each grid.

Another mobile source of pollution in the St. Louis area is the operation of ships, boats, and barges on the Mississippi and Missouri Rivers which traverse the St. Louis metropolitan area. The amount of diesel fuel consumed within the study area was obtained from the Port Authority and Army Corps of Engineers. They made fuel use estimates by river sections, thus, making it easy to translate this information onto the grid-coordinate system.

C. Solid Wastes. The open burning and incineration of waste can be a major source of pollution. The estimation of the amounts of pollutants emitted requires data on the amounts of waste burned.

In the St. Louis area, the primary modes of refuse disposal are municipal incinerators in the City of St. Louis, non-burning sanitary landfills in the surrounding area, and a multitude of small incinerators serving industrial, commerical, and large residential establishments. The municipal incinerators were considered as point sources; the amount of waste burned at each site were obtained and their emissions were calculated individually. The amount of waste incinerated locally was estimated by determining the difference between the total amount of waste generated in the area (assumed to be 4.5 kg/person/day) and that disposed at central facilities, e.g., municipal incinerators and landfills. This difference was assumed to be incinerated on site. The emissions from on-site incineration were allocated to the grids according to population densities.

D. Industrial Processes. The emissions generated by the manufacture of goods must be calculated on a source-by-source basis. Thus, only the major manufacturing establishments can generally be included. In the St. Louis area, information on the types of industries present, their processes and production rates, and the types of air pollution control equipment were derived from detailed questionnaires which the individual industrial firms had supplied to the operating control agencies. This information, together with average emission factors, provided the basis for industrial process emissions.

III. Results

The air pollution emissions for the St. Louis metropolitan area are summarized in Table 2. The emissions of sulfur oxides and

TABLE 2

SUMMARY OF AIR POLLUTANTS IN THE ST. LOUIS STUDY AREA, 1969

(10^3 Kg/year)

Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	2,220	2,990	509,280	93,240	48,160
Other	1,890	2,760	8,100	7,000	2,900
Subtotal	4,110	5,750	517,380	100,240	51,060
Stationary Fuel Combustion					
Industry	132,600	60,900	2,740	3,140	28,800
Residential	11,300	2,760	4,750	1,200	3,630
Commercial – Institutional	8,800	4,940	630	250	2,270
Elecric Generation	405,900	49,400	3,480	1,220	99,400
Subtotal	558,600	118,000	11,600	5,810	134,100
Refuse Disposal					
Incineration	510	2,180	2,430	860	910
Open Burning	200	3,140	16,670	5,880	1,180
Subtotal	710	5,320	19,100	6,740	2,090
Industrial Processes	111,000	37,500	307,200	23,100	1,600
Evaporative Losses	—	—	—	55,500	—
GRAND TOTAL *	674,000	167,000	855,000	191,000	189,000

* rounded

particulates in 1969 amounted to 674,000 tons and 167,000 tons, respectively. For hydrocarbons, oxides of nitrogen, and carbon monoxide, the estimated annual emissions were 191,000, 189,000, and 855,000 tons respectively. The geographical distribution of these emissions are illustrated in Figures 4 through 8 which show the emission densities of these pollutants. The major sources of air pollution in the St. Louis area are steam-electric power plants, industrial operations, and motor vehicle travel. The locations of major point sources are shown in Figure 9.

A. Stationary Fuel Combustion. All sources which burn fuel for the purpose of space or process heating are included in this category. This category is further classified by source type, i.e., steam-electric generating plants, industrial plants, residential heating, and commercial, institutional and governmental facilities. This classification is valuable in collecting inventory information, in evaluating the pollution problems, and in developing feasible control strategies.

During 1969, more than 8.9 million tons of coal, 1.4 billion liters of fuel oil, and 6 billion cubic meters of natural gas were consumed in the St. Louis metropolitan area. Coal and natural gas were the primary sources of heat and power accounting for 50 and 40 percent, respectively, of the total energy produced. Tables 3 and 4 present a summary of the fuel consumption by consumer type as well as describe the average qualities of the fuels used, e.g., sulfur, ash, and heat contents.

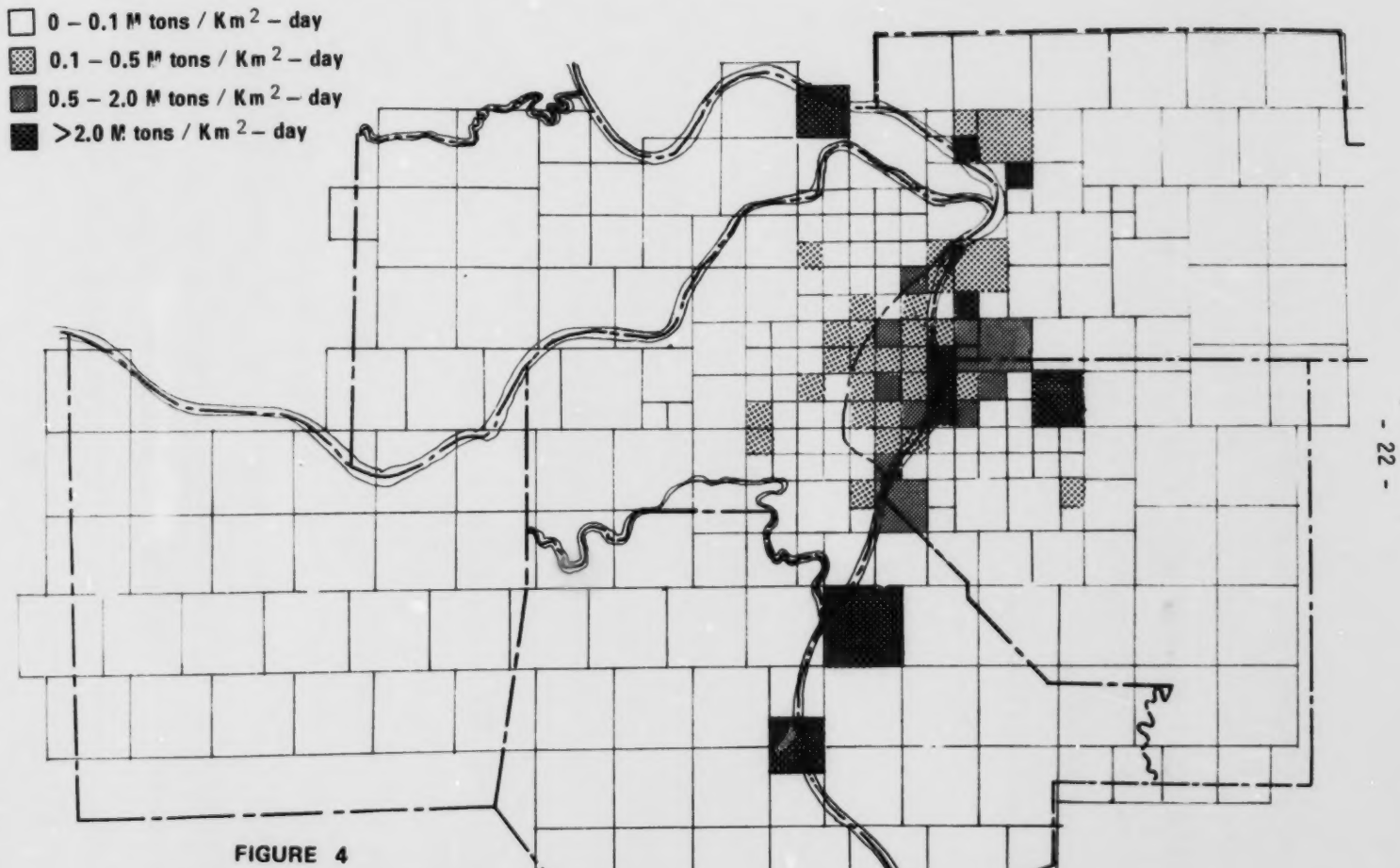


FIGURE 4

SULFUR OXIDES EMISSION DENSITIES FOR ST. LOUIS STUDY AREA, 1969

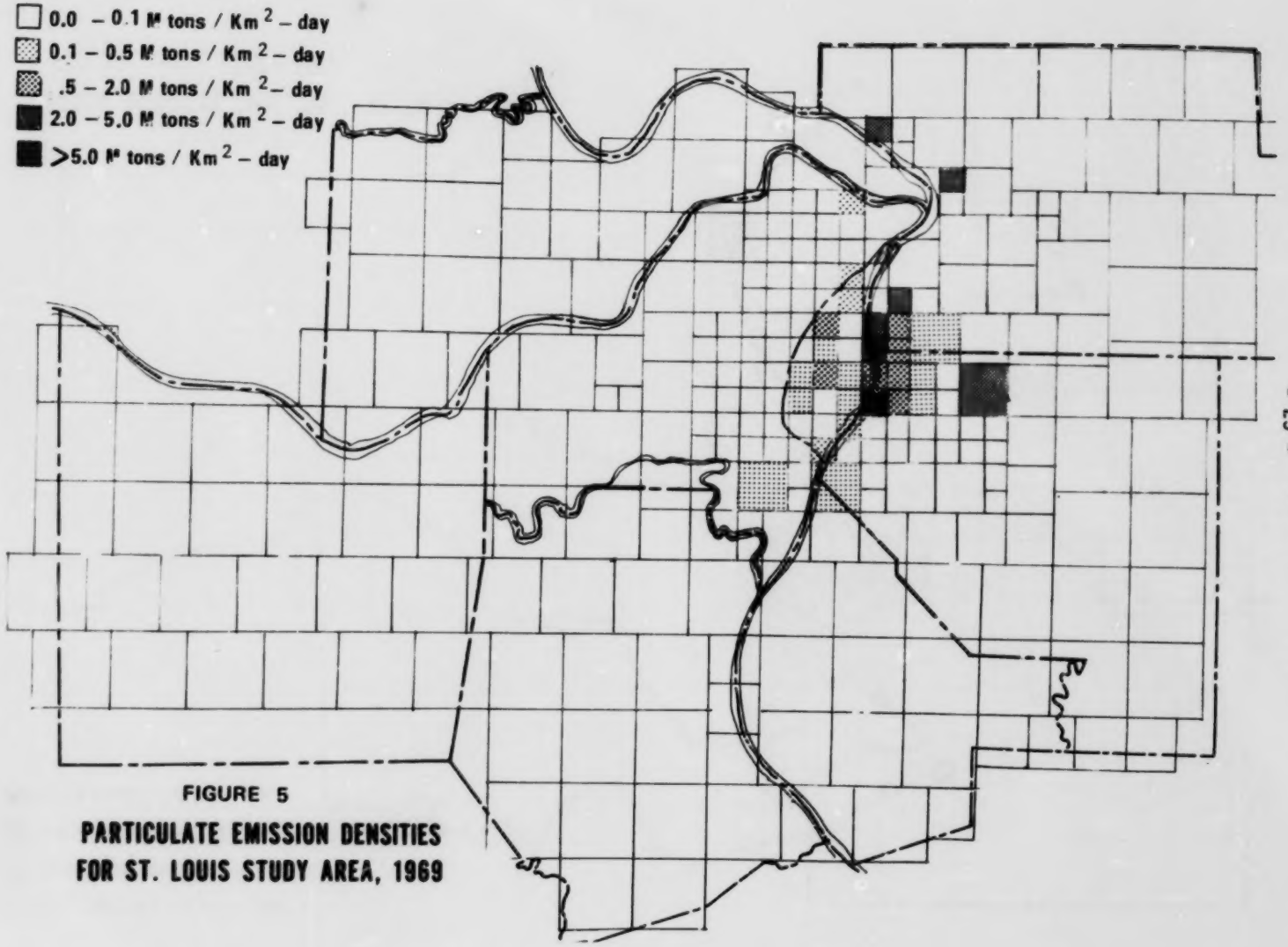


FIGURE 5

PARTICULATE EMISSION DENSITIES FOR ST. LOUIS STUDY AREA, 1969

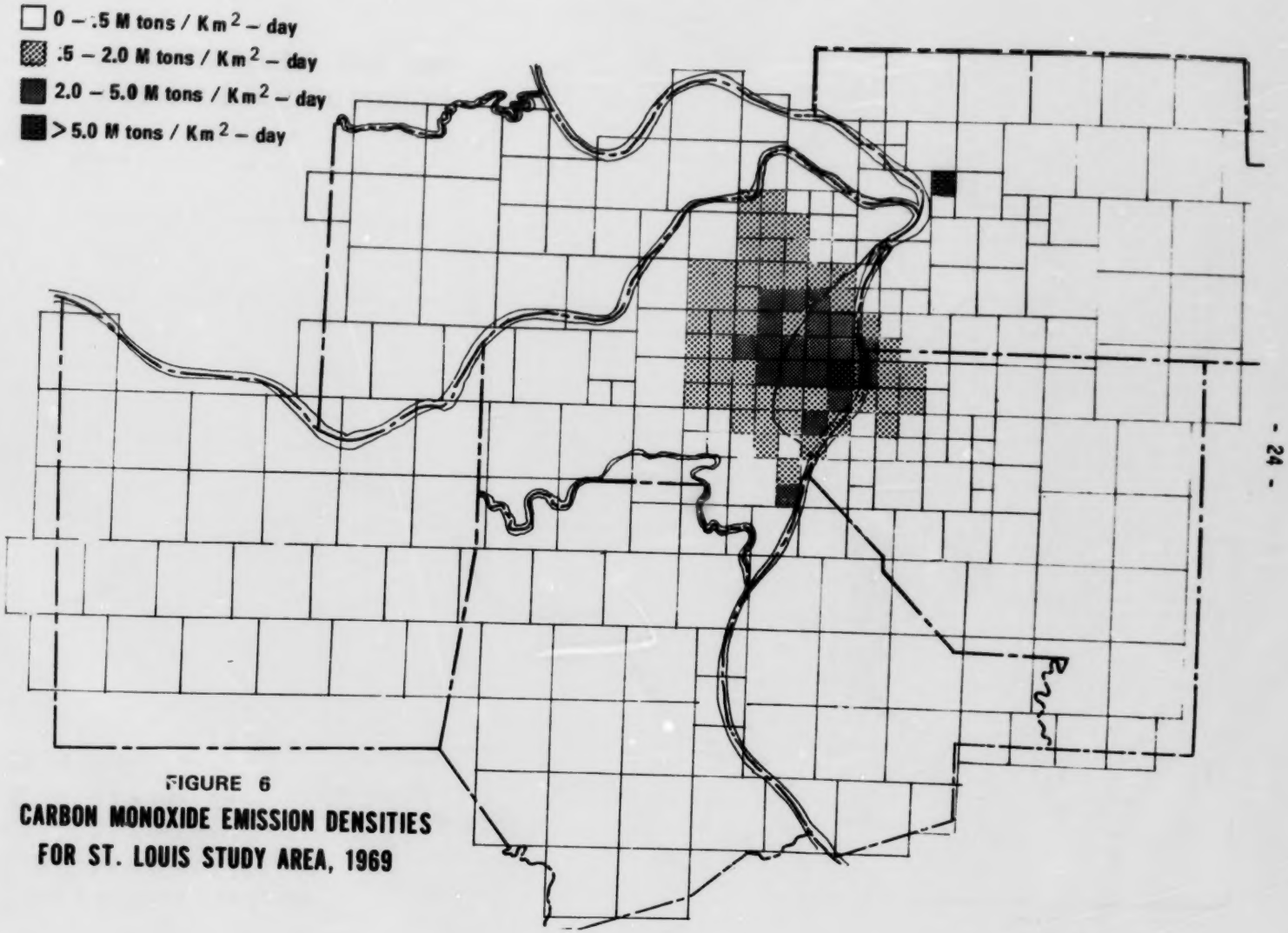


FIGURE 6

CARBON MONOXIDE EMISSION DENSITIES FOR ST. LOUIS STUDY AREA, 1969

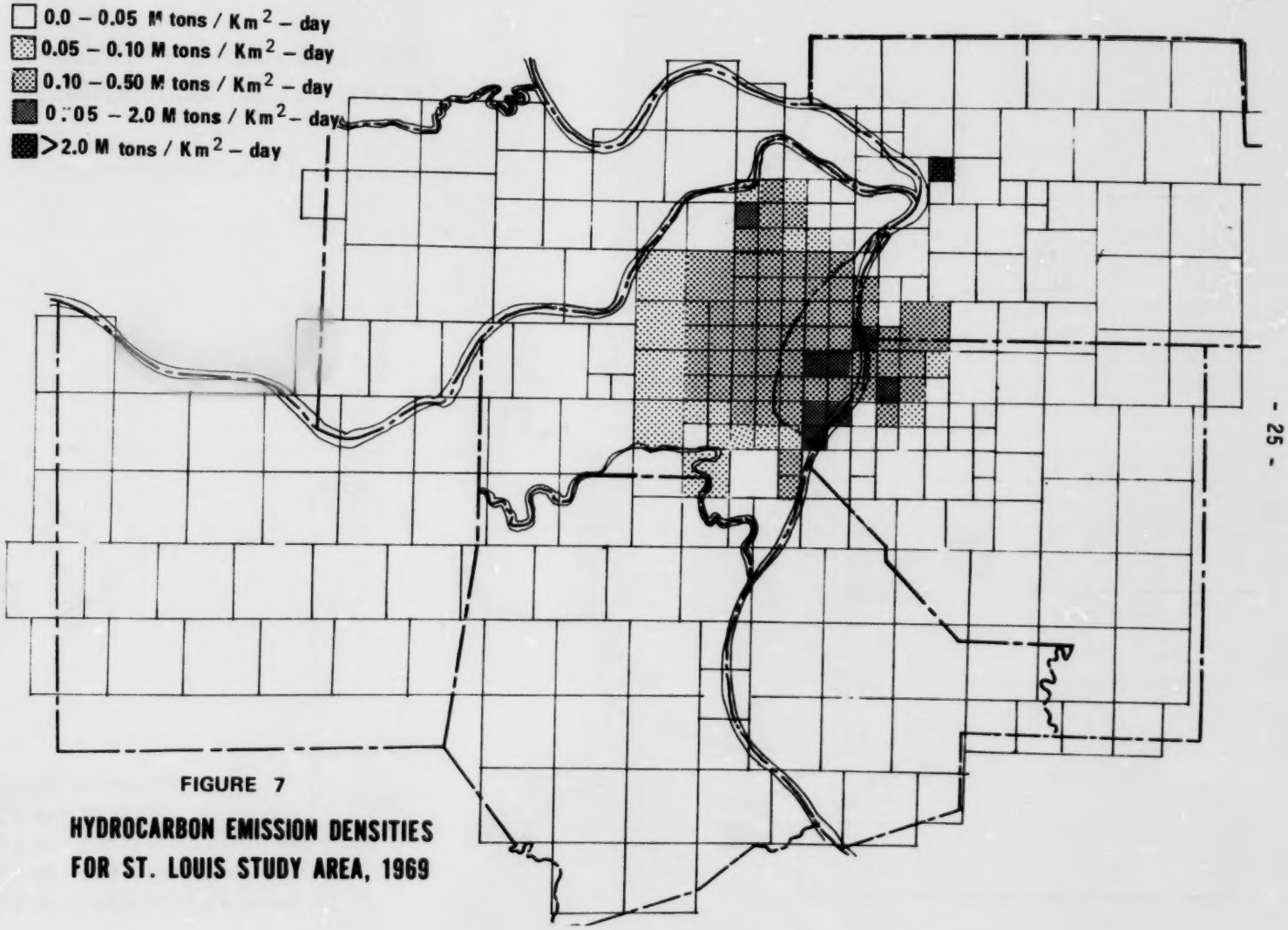


FIGURE 7

HYDROCARBON EMISSION DENSITIES FOR ST. LOUIS STUDY AREA, 1969

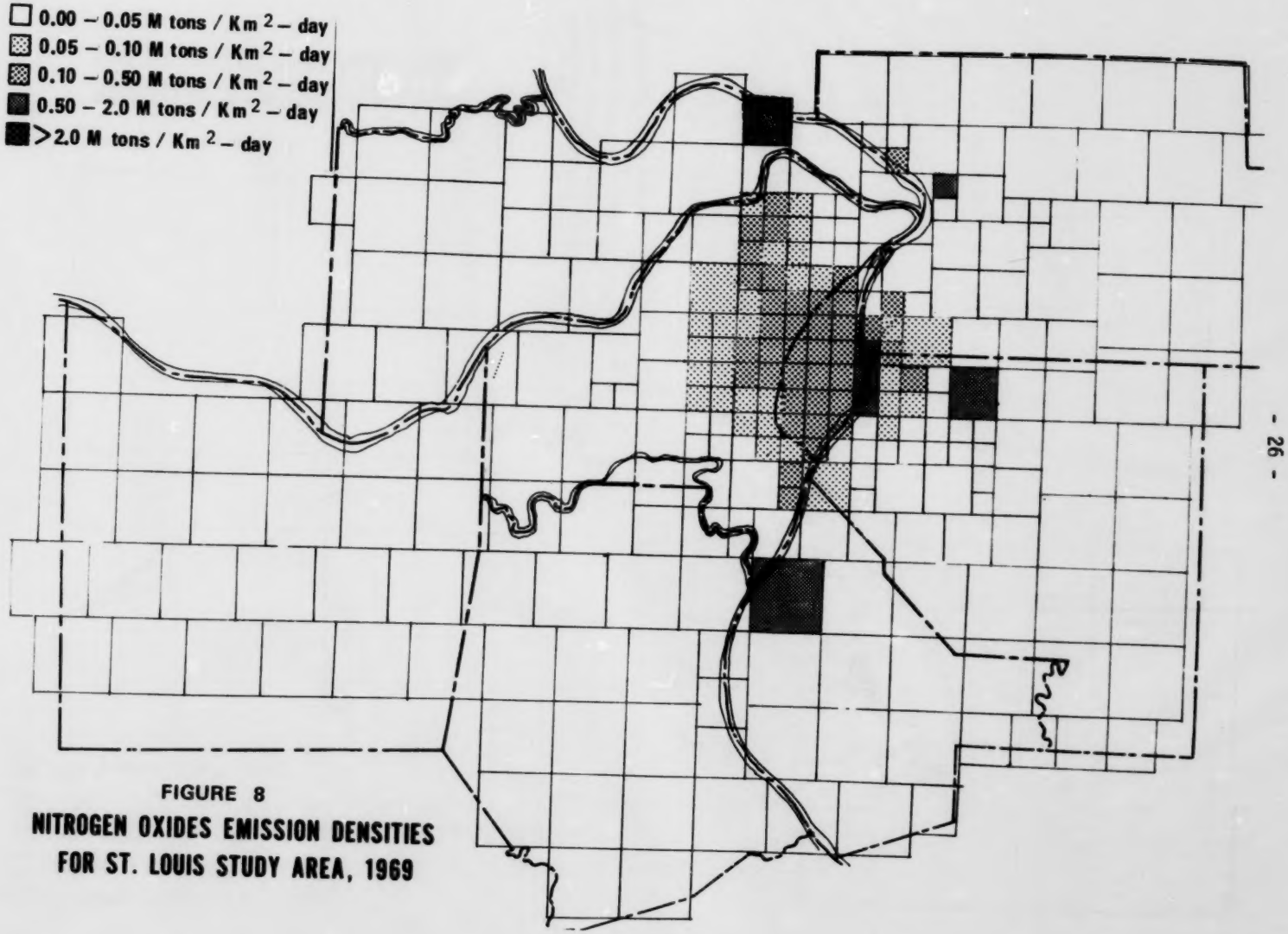


FIGURE 8
NITROGEN OXIDES EMISSION DENSITIES
FOR ST. LOUIS STUDY AREA, 1969

FIGURE 9

MAJOR POINT SOURCES IN THE ST. LOUIS AREA

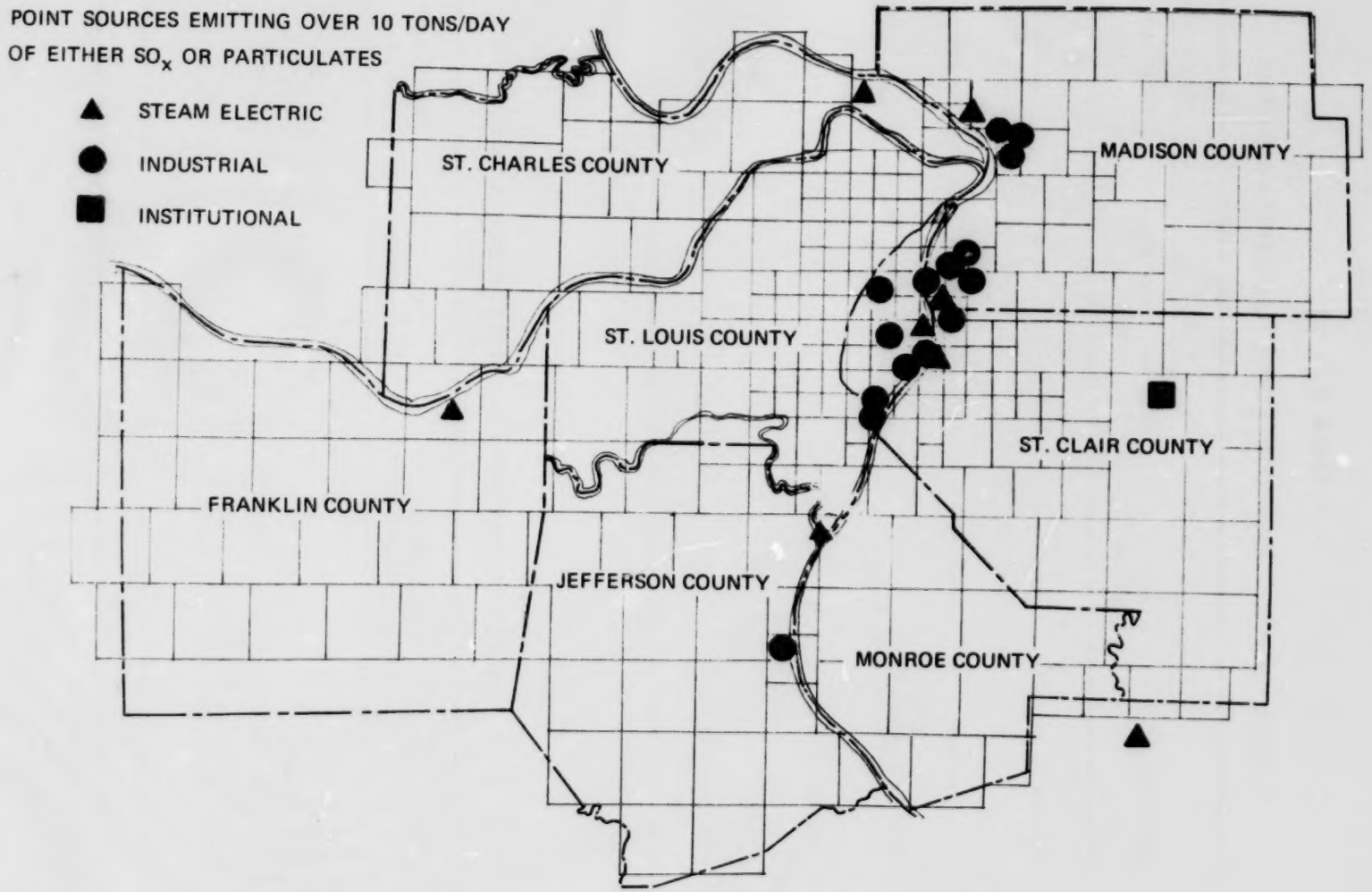


TABLE 3

SUMMARY OF FUEL CONSUMPTION IN THE ST. LOUIS STUDY AREA, 1969

Consumer	Coal (10^6 Kg)	Fuel Oil		Natural Gas (10^6 M^3)
		Distillate	Residual	
		10^6 L.		
Residential	150	514	n	2,070
Commercial – Institutional	140	84	n	660
Steam - Electric Utilities	6,940	2	40	250
Industrial	1,710	n	770	2,870
TOTAL	8,940	600	810	5,850
Energy (10^{15} cal.)	64.5	6.0	8.1	52.2

n = negligible

TABLE 4

FUEL QUALITIES IN THE ST. LOUIS STUDY AREA, 1969

Fuel	Sulfur (% by weight)	Ash (% by weight)	Heat Content (cal / g)
Coal	1 - 3.5	8 - 11	7,200
Distillate Fuel Oil	0.2 - 0.3	—	11,400
Residual Fuel Oil	1.5 - 2.2	—	10,200
Natural Gas	n	—	8.9×10^6 cal / M^3

n = negligible

Emissions from the burning of fuels are detailed in Table 5. This category of sources accounts for the vast majority of sulfur oxide emissions (82 percent), particulate emissions (71 percent), and nitrogen oxides (70 percent). Essentially, all of these emissions can be attributed to the burning of coal. Coal combustion produces 95 percent of the sulfur oxides, 96 percent of the particulate matter, and 83 percent of the nitrogen oxides resulting from stationary fuel combustion. In terms of consumer class, the steam-electric power plants (eight in St. Louis area) are the principal emitters of these three pollutants.

B. Mobile Fuel Combustion. The emissions attributed to mobile sources of pollution are summarized in Table 6. The motor vehicle is responsible for the majority of carbon monoxides, hydrocarbons, and considerable amounts of oxides of nitrogen. In 1969, nearly 510,000 tons of carbon monoxide, approximately 92,000 tons of hydrocarbons, and 48,000 tons of nitrogen oxides were discharged in motor vehicle exhaust. These emissions resulted from automobiles and trucks that annually travel more than 9 billion vehicle miles. Of primary importance in combating air pollution from motor vehicles is the need to reduce peak concentrations. In terms of emission rates, the contribution of vehicles during 1600 to 1700 hours accounts for over eight percent of the daily load of carbon monoxide from motor vehicles. Similarly, a single eight-hour period (1100-1900 hours) accounts for 55 percent of daily motor vehicle emissions.

C. Refuse Disposal. Because of the large quantities of waste

TABLE 5

EMISSIONS FROM FUEL COMBUSTION FOR THE ST. LOUIS STUDY AREA, 1969
10^3 Kg/year

Source	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Coal					
Industrial	103,600	57,670	2,700	900	12,800
Steam-Electric	404,400	49,280	3,470	1,040	97,370
Residential	9,480	1 510	3,780	760	380
Commercial and Institutional	8,410	4,580	410	130	750
Sub-total	525,890	113,040	10,360	2,830	111,300
Fuel Oil					
Industrial	28,960	2,310	20	320	7,600
Steam-Electric	1,530	40	n	30	530
Residential	1,780	620	310	190	740
Commercial and Institutional	360	160	n	30	740
Sub-total	32,630	3,130	330	570	9,610
Natural Gas					
Industrial	30	860	20	1,920	8,320
Steam-Electric	n	60	n	160	1,580
Residential	20	630	660	270	2,490
Commercial and Institutional	10	200	210	90	800
Sub-total	60		890	2,430	13,250
TOTAL *	558,600	118,000	11,580	5,830	134,160

*Rounded

TABLE 6

AIR POLLUTANT EMISSIONS FROM TRANSPORTATION
IN THE ST. LOUIS STUDY AREA, 1969

(10^3 Kg / year)

Source	Activity	SO_x	Particulate	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Motor Vehicle						
Gasoline	24 1 x 10^6 v m/day	1,610	2,700	506,290	92,740	43,230
Diesel	0 7 x 10^6 v.m/day	610	290	2,990	500	4,930
Vessels	9 5 x 10^6 gal diesel	180	450	270	210	310
Trains	32 x 10^6 gal diesel	960	370	1,040	740	1,110
Aircraft	928 x 10^3 operations	750	1,930	6,720	6,070	1,450
TOTALS		4,110	5,750	517,310	100,260	51,030

TABLE 7
SOLID WASTE DISPOSAL FOR THE ST. LOUIS STUDY AREA, 1969

Disposal Method	Quantity Disposal 10^6 kg	Emmissions (10^3 kg)				
		Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Landfill	2,900	0	0	0	0	0
Open Burning						
Dumps	0	0	0	0	0	0
On-site	390	200	3,140	16,660	5,880	1,180
Incineration						
Municipal	210	160	550	110	160	210
On-site	470	350	1,630	2,320	700	700
TOTAL	3,970	710	5,320	19,090	6,740	2,090

being disposed in sanitary landfills, the emissions from the burning of waste material do not add substantially to the total air pollution in the St. Louis area (sulfur oxides-0.1 percent, particulates-3.1 percent). Table 7 presents a summary of solid waste disposal practices and the resulting estimated air pollutant emissions.

D. Industrial Processes. Emissions from this category are substantial. The major industrial process sources include a lead smelter, several sulfuric acid plants, four cement plants, four oil refineries, many iron or steel foundry operations, a multitude of grain storage elevators, and iron and steel mills with by-product coking ovens. Industrial emissions by source type are tabulated in Table 8.

TABLE 8

EMISSIONS FROM INDUSTRIAL PROCESSES IN THE ST. LOUIS STUDY AREA, 1969

(10^3 kg/year)

Processes	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Coke Manufacturing	6,520	2,220	800	2,670	20
Steel	---	3,170	---	---	---
Grain	---	17,320	---	---	---
Cement	---	3,010	---	---	---
Primary Smelting	80,500	200	---	---	---
Sulfuric Acid	9,840	---	---	---	---
Oil Refining	13,200	5,370	304,720	11,300	1,560
Foundries	---	2,090	---	---	---
Glass	---	760	---	---	---
All Others	940	3,300	1,680	9,130	20
TOTAL	111,000	37,440	307,200	23,100	1,600

AIR QUALITY MONITORING

I. Introduction

The St. Louis metropolitan area has a long history of air pollutant measurement and monitoring activities. In many respects, the air quality in St. Louis has been studied more thoroughly and for longer periods of time than in most United States urban centers, especially in the case of sulfur dioxide and particulate pollution. Some measurements of sulfur oxide pollution were made as early as 1936 and 1937. In 1963 and 1964, a major study of SO_2 and particulate pollution was undertaken by the local air pollution control agencies in cooperation with the Federal Government.

During the last several years, new monitoring systems have been implemented in the St. Louis region. Because of the inter-jurisdictional nature of St. Louis, the total monitoring program consists of networks and stations operated by a number of different local, State, and Federal agencies. The networks consist of two types of stations--comprehensive monitoring stations where essentially all of the pollutants of interest are automatically and continuously measured and simple stations where only one or two pollutants are measured at periodic intervals. Overall, there are ten comprehensive monitoring stations in the St. Louis area, supplemented by approximately 30 stations where measurements of total suspended particulates

(and in some cases SO_2) are made on a weekly or bi-weekly schedule. The distribution of these stations by operating agency is shown in Table 9. For purposes of the NATO/CCMS air pollution case study of St. Louis, the existing monitoring system was deemed adequate to define the air quality levels.

This section of the report describes the existing St. Louis area monitoring system and summarizes the data derived during the fall and winter of 1970-1971 (Phase I) and portions of 1971-1972 (Phase II). The data obtained during the winter season (December 1970 - February 1971) was used to develop the working air quality model for application in projecting future air quality for sulfur dioxide and suspended particulates and in assessing various control alternatives.

II. Monitoring Network

The locations of monitoring/sampling stations are shown in Figure 10. The regional monitoring activity is composed of stations and networks operated by five air pollution control agencies--State of Illinois, State of Missouri, St. Louis City, St. Louis County, and the U. S. Environmental Protection Agency. The instrumentation, analyses techniques, and the frequencies of sampling are somewhat variable among the networks.

Information on the ambient concentrations of air pollutants in the St. Louis area was increased substantially in late 1970 with the installation by the City and County of St. Louis of eight

TABLE 9 NUMBER OF MONITORING INSTRUMENTS IN STUDY AREA

	Continuous					
	CO	HC	NO_X	Oxidants	SO_2	Part.
COUNTY OF ST. LOUIS	5	5	5	5	4	6
CITY OF ST. LOUIS	5	5	5	5	5	10
STATE OF ILLINOIS	4	1	1	1	3	14
STATE OF MISSOURI	-	-	-	-	-	13
ENVIRONMENTAL PROTECTION AGENCY	1	1	1	1	1	2

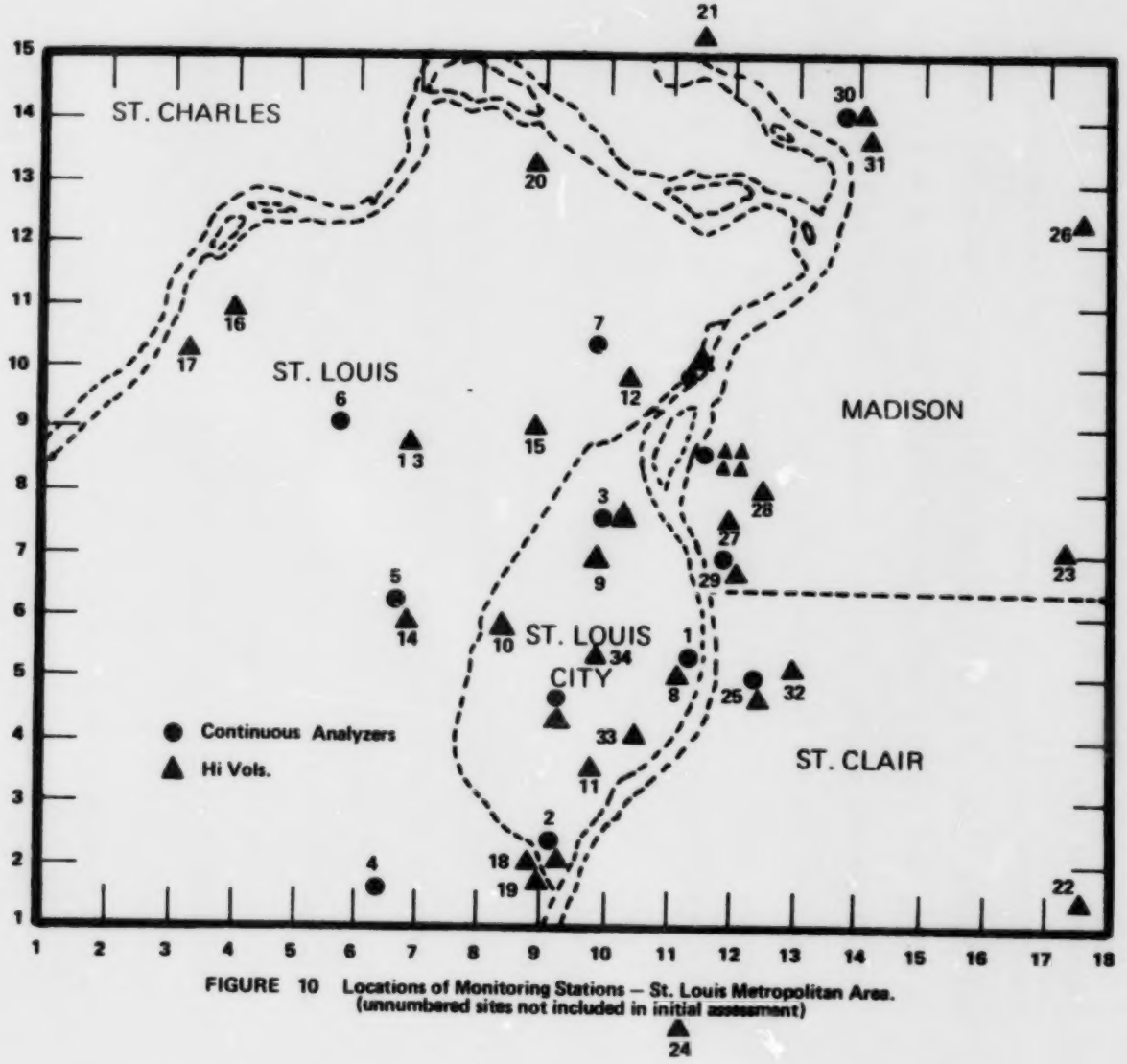


FIGURE 10 Locations of Monitoring Stations – St. Louis Metropolitan Area.
(unnumbered sites not included in initial assessment)

comprehensive monitoring stations. In late 1972, two stations were added to this network. These stations, locate throughout the City and County, are linked by a computer-controlled telemetry system to a central receiving station. Raw data from the stations are received on a 3-minute basis from which hourly averages are computed. Although each of these two agencies operate their own stations, both agencies utilize the same telemetry system. The most complete stations are equipped to measure the six common gaseous pollutants--SO_2, CO, Ox, HC, NO_2, and nitric oxide; particulate matter; wind speed; wind direction; and temperature. This totals 10 parameters. All stations have ten parameters. In addition, stations 1, 2 and 3 measure 11 parameters. At these stations visibility and suspended particulates are continuously monitored by the use of an integrating nephalometer. Each station consists of multiple gas analyzers for the above pollutants which sample from a common intake manifold located about 10 feet above ground. In addition to the stations, the City and County operate a greater number of total suspended particulate stations. At these stations, 24-hour samples are collected on a weekly basis. Additional information on the gaseous pollutants is also continually gathered by the State of Illinois and the Environmental Protection Agency (EPA). In late 1968, the State of Illinois installed three continuous monitoring stations in the Illinois portion of the metropolitan area. At these stations, continuous measurements are made of SO_2, CO, total hydrocarbons, and oxidants. Since 1964, EPA (and its predecessor agencies) has operated a comprehensive monitoring station in the center of St. Louis City. This station provides a continuous data base on levels

of all primary pollutants for a 12-year period. These agencies as well as the State of Missouri also operate a number of suspended particulate sampling stations.

Although there is increased tendency toward the use of common methods of measurement, a variety of methods is still being employed. The methods of analysis used by the various agencies are summarized in Table 10.

III. Results

The air quality information presented in this report consists of three sets of data. The first set includes data on sulfur dioxide and suspended particulates for the period from September 1, 1970, through February 28, 1971. These data, described in the earlier draft of the Guidelines and repeated here, were used to validate the diffusion model. The second set of data consists of SO_2 and TSP measurements made since February 28, 1971. These data provide a more comprehensive view of the distribution and variability of these pollutants in the St. Louis area. The third set of data consists of the measurements of the Phase II pollutants and are representative for the most part of 1971 and portions of 1972. It is important to note that data from all of the stations are not included in the analysis because of differences of data handling and reporting techniques.

A. Initial Assessment of SO_2 and TSP. The ambient concentrations observed at seven SO_2 monitoring stations and at 25 TSP stations during the six-month period from September 1970 - February 1971 are summarized

TABLE 10 METHODS OF ANALYSES

	SO_2	PART.	CO	TOTAL HYDRO-CARBONS	OXIDANT	NITROGEN DIOXIDE
CITY OF ST. LOUIS	Conductometric	Hi-vol	Non-dispersive infra-red	Flame ionization	Colorimetric (Neutral KI)	Saltzman
COUNTY OF ST. LOUIS	Colorimetric (West-Gaeke)	Hi-vol	Non-dispersive infra-red	Flame ionization	Colorimetric (Neutral KI)	Saltzman
STATE OF ILLINOIS	Colorimetric (West-Gaeke)	Hi-vol	Non-dispersive infra-red	Flame ionization	Colorimetric (Neutral KI)	———
STATE OF MISSOURI	———	Hi-vol	———	———	———	———
EPA	Colorimetric (Conductometric before 1970)	Hi-vol	Non-dispersive infra-red	Flame ionization (Total and Methane)	Chemilumi-nescence	Chemilumi-nescence and Saltzman

in Table 11. For sulfur dioxide, the average concentrations ranged from 208 $\mu g/m^3$ for a station in the industrial southern part of St. Louis to 34 $\mu g/m^3$ in the suburban portions of St. Louis County. It is important to note that SO_2 data for the three stations in the Illinois portion of the St. Louis metropolitan area were not available for the comparable time period. The 1970 averages for the three stations were as follows: Venice (M-29) 56 $\mu g/m^3$, Wood River (M-30) 45 $\mu g/m^3$ and East St. Louis (M-25) 40 $\mu g/m^3$. The maximum daily concentration of 1555 $\mu g/m^3$ occurring during this time period was observed at station M-2. At other locations, the maxima are much lower ranging from 172 $\mu g/m^3$ at station M-4 to 632 $\mu g/m^3$ at station M-3.

In the case of total suspended particulate concentrations, two distinct areas of high ambient levels are clearly evident. One of these is in the Granite City area of Illinois with the other being in the southern part of the City of St. Louis. The highest six-month average of 186 $\mu g/m^3$ was recorded at station M-28 (Granite City); the next highest average of 184 $\mu g/m^3$ was observed at station M-18. The highest 24-hour value of 1209 $\mu g/m^3$ was observed at station M-18. In general, the TSP concentrations were higher near the center of the metropolitan area decreasing with distance outward.

Some indication of the seasonal influence on air quality levels in St. Louis may be obtained by comparing the average concentrations for periods of September-November and December-February. Such comparisons are shown in Tables 12 and 13 for TSP and SO_2, respectively.

TABLE 11

TOTAL SUSPENDED PARTICULATE AND SULFUR DIOXIDE AVERAGE CONCENTRATIONS IN ST. LOUIS SEPTEMBER 1970 - FEBRUARY 1971

	TSP ($\mu g/m^3$)			SO_2 ($\mu g/m^3$)		
Station Number	Avg.	Max.	Min.	Avg.	Max.	Min.
M-1	–	–	–	47	255	0
M-2	126	266	47	208	1555	0
M-3	–	–	–	81	632	0
M-4	–	–	–	39	172	0
M-5	–	–	–	52	364	0
M-6	–	–	–	34	341	0
M-7	–	–	–	44	442	0
M-8	164	376	46			
M-9	85	149	33			
M-10	68	103	36			
M-11	102	269	33			
M-12	89	263	15			
M-13	60	115	28			
M-14	83	143	30			
M-15	79	170	20			
M-16	76	117	38			
M-17	47	130	20			
M-18	184	1209	32			
M-19	70	140	32			
M-20	62	127	21			
M-21	87	155	39			
M-22	82	124	48			
M-23	83	126	48			
M-24	79	211	33			
M-25	102	170	17			
M-26	78	123	40			
M-27	141	217	61			
M-28	186	284	89			
M-29	110	311	51			
M-30	112	169	44			
M-31	119	350	28			

ST. LOUIS AVERAGE TSP CONCENTRATIONS (ug / m^3)

Station Number	September – November 1970	December 1970 – February 1971
M-2	126.0	126.0
M-8	123.7	204.7
M-9	80.3	89.3
M-10	58.3	77.3
M-11	105.7	98.7
M-12	92.3	86.0
M-13	55.0	65.3
M-14	88.0	78.0
M-15	74.3	84.3
M-16	75.5	76.0
M-17	59.3	28.0
M-18	230.7	136.7
M-19	66.7	73.0
M-20	61.3	62.0
M-21	87.0	87.9
M-22	84.0	79.0
M-23	94.3	72.1
M-24	71.3	84.9
M-25	100.7	104.2
M-26	80.0	74.5
M-27	115.0	164.0
M-28	171.3	201.4
M-29	110.3	108.6
M-30	115.0	108.9
M-31	142.7	95.6

TABLE 13

ST. LOUIS AVERAGE SO_2 CONCENTRATIONS (ug / m^3)

Station Number	September – November 1970	December 1970 – February 1971
M-1	46.8	18.2
M-2	140.8	293.8
M-3	52.0	106.6
M-4	31.2	46.8
M-5	46.8	53.8
M-6	31.2	39.0
M-7	52.0	36.4

For TSP, no definite pattern of increased concentrations can be shown. Although considerable increases in levels were recorded at some stations, namely M-8 and M-27, the general pattern is that of relatively constant levels. This is not the case for SO_2, where notable increases in concentrations were recorded at five out of the seven stations. The seasonal influences on ambient SO_2 levels are further shown in Figure 11, where the average hourly concentrations are shown for each season. This figure was constructed from measurements recorded at station M-1 during 1968.

Three of the SOx monitoring stations were selected to compare the hourly average concentrations and to observe any diurnal patterns. Figure 12 shows the average hourly concentrations for December 1971 through February 1971 for stations M-1, M-3, and M-6. The curves for all three stations show roughly the same daily pattern with the peak concentrations occurring in late morning.

B. SOx and TSP Data Collected Since Initial Assessment.

Tables 14, 15, and 16 and Figure 13 show some of the particulate and sulfur dioxide data collected since the initial assessment. The TSP data is from the City of St. Louis, and the SOx data is from the City and County.

Particulate data show no apparent long-term or seasonal variations. The levels in Table 14 correspond roughly to the data collected in the initial assessment, and seasonal variations appear to occur at different sites, but not for the City as a whole. For SO_x, however,

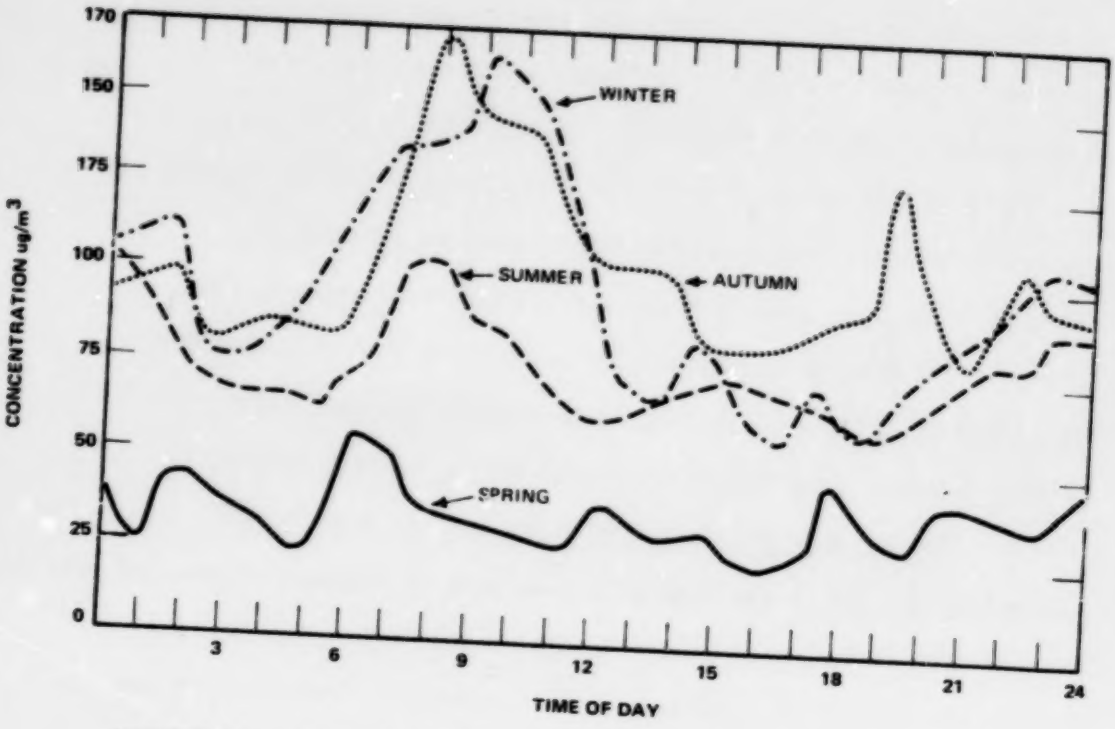


FIGURE 11 Seasonal SO_2 Patterns at the EPA CAMP Station (1967 and 1968).

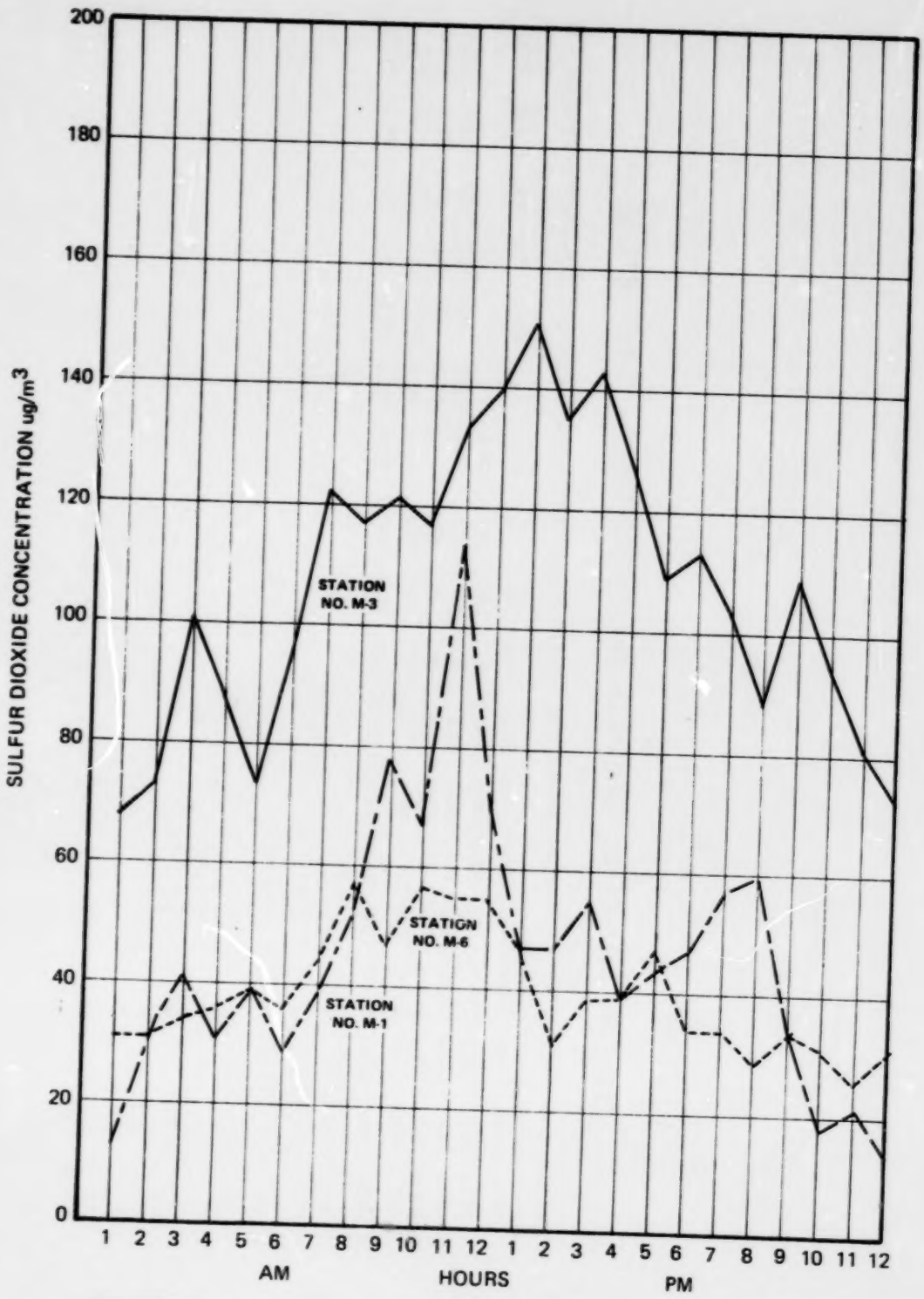


FIGURE 12 Average Hourly SO_2 Concentrations in St. Louis (Dec. 1970 - Feb. 1971).

TABLE 14 CITY OF ST. LOUIS TSP CONCENTRATIONS, 1971 AND 1972 ($\mu g/m^3$)

		STATION #1		STATION #2		STATION #3		STATION #5		STATION #10		STATION #11		STATION #9		STATION #33		STATION #34	
		Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
I	1971	101.6	247.2	136.2	265.7	114.8	205.8	70.9	128.3	75.2	171.5	74.9	130.6	*	*	*	*	*	*
II	1971	130.0	237.1	132.3	196.8	134,9	197.2	93.7	133.1	105.3	188.7	98.5	145.1	116.3	159.4	91.3	120.9	92.6	123.3
III	1971	108.5	206.1	166.0	478.8	118.6	229.2	83.6	146.0	99.4	165.2	78.7	131.8	101.9	144.7	86.5	145.7	88.4	136.0
IV	1971	97.1	202.3	171.8	333.0	128.1	263.2	84.1	202.2	85.5	218.5	69.0	111.9	90.1	179.1	75.7	173.9	75.2	157.1
I	1972	96.8	128.7	139.1	971.0	118.5	222.4	77.0	160.0	77.8	255.1	63.0	96.1	75.4	128.6	73.5	109.2	79.1	117.0

TABLE 15 ST. LOUIS COUNTY AND CAMP STATION.

DATA FOR SOx AND PHASE II POLLUTANTS, 1971 AND 3rd QUARTER 1972 ($\mu g/m^3$)

	AVG. TIME	STATION	1971 1st Qtr. Avg.	1st Qtr. Max.	2nd Qtr. Avg.	2nd Qtr. Max.	3rd Qtr. Avg.	3rd Qtr. Max.	4th Qtr. Avg.	4th Qtr. Max.	Annual Avg.	Annual Max.	1972 3rd Qtr. Avg.	1972 3rd Qtr. Max.
SO_2	24hr.	#10	49	135	49	130	60	195	46	190	52	195		
		9	43	130	34	110	49	155	46	165	43	165		
		6	–	–	–	–	–	–	43	115	–	–		
		7	31	125	43	145	49	210	43	245	40	245		
		8	46	135	29	90	63	175	52	245	46	245		
		Camp	85	–	55	–	30	–	30	–	55	–		
OXIDANTS	1hr.	#10	15	120	35	160	43	215	37	310	31	310	37	140
		9	12	110	37	215	43	235	27	240	29	240	37	265
		6	–	–	–	–	–	–	53	220	–	–	63	300
		7	8	41	31	185	49	195	29	190	29	195	55	260
		8	12	105	37	185	33	155	14	175	24	185	51	200
		Camp	20	140	39	255	39	180	20	160	29	255	–	–
CO(mg/m^3)	1hr.	#10	3.0	19.6	3.0	12.0	4.5	12.6	4.6	28.6	3.8	28.6	6.0	13.2
		9	3.8	17.8	3.1	15.0	2.9	12.6	5.9	25.2	3.9	25.2	10.5	27.5
		6	–	–	–	–	–	–	4.4	12.6	–	–	–	–
		7	3.0	22.6	2.3	16.1	2.5	13.2	3.9	31.2	2.9	31.2	4.8	24.6
		8	3.0	9.9	3.6	16.1	3.1	13.7	3.9	19.3	3.5	19.3	2.2	6.7
		Camp	3.6	24.2	5.6	20.7	5.8	18.4	5.3	38.0	5.1	38.0	–	—
NO_2	24hr.	#10	–	–	90	–	92	–	89	–	90	–	86	274
		9	–	–	84	–	86	–	81	–	84	–	62	244
		6	–	–	–	–	–	–	58	–	–	–	42	244
		7	–	–	58	–	72	–	78	–	68	–	72	378
		8	–	–	81	–	66	–	62	–	70	–	70	246
	1hr.	Camp	60	190	80	260	80	170	60	240	70	260	–	–
THC	1hr.	#10	–	–	–	–	–	–	–	–	–	–	1050	8200
		9	–	–	–	–	–	–	–	–	–	–	1050	3410
		6	–	–	–	–	–	–	–	–	–	–	460	1110
		7	–	–	–	–	–	–	–	–	–	–	1110	3730
		8	–	–	–	–	–	–	–	–	–	–	2750	2420
		Camp	1,170	2,220	1,240	5,240	1,510	5,700	1,310	3,540	1,310	5,700	–	–

TABLE 16 THIRD QUARTER, 1972 AIR QUALITY DATA FOR ST. LOUIS CITY

		JULY		AUG.		SEPT.		1972 3rd quarter	
		AVG.	MAX.	AVG.	MAX.	AVG.	MAX.	AVG.	MAX.
SO_2($\mu g/m^3$)									
1hr.	1	117	1,170	134	1,480	60	752	90	1,480
	2	77	1,120	83	1,600	190	610	110	1,600
	3	72	670	110	1,120	92	700	90	1,120
OXIDANTS ($\mu g/m^3$)									
1hr.	1	60	335	60	470	20	255	40	335
	2	20	255	60	195	40	255	40	255
	3	60	335	60	295	20	355	40	355
CO (mg/m^3)									
1hr.	1	5.6	16,8	5.6	10.9	4.4	16.8	5.2	16.8
	2	–	–	4.9	25.0	5.4	24.7	5.2	25.0
	3	4.1	13.1	5.7	20.5	5.2	15.2	5.1	20.5
NO_2($\mu g/m^3$)									
24hr.	1	60	430	–	–	60	360	60	430
	2	40	260	40	320	20	110	40	320
	3	130	550	60	230	40	240	80	550
THC($\mu g/m^3$)									
1hr.	1	920	2,160	1,310	5,110	–	–	1,110	5,110
	2	1,050	4,460	1,375	6,160	–	–	1,180	6,160
	3	850	2,550	9,800	3,140	–	–	920	3,160

FIGURE 13 MONTHLY AVERAGES OF SO_2 FROM EPA CAMP STATION

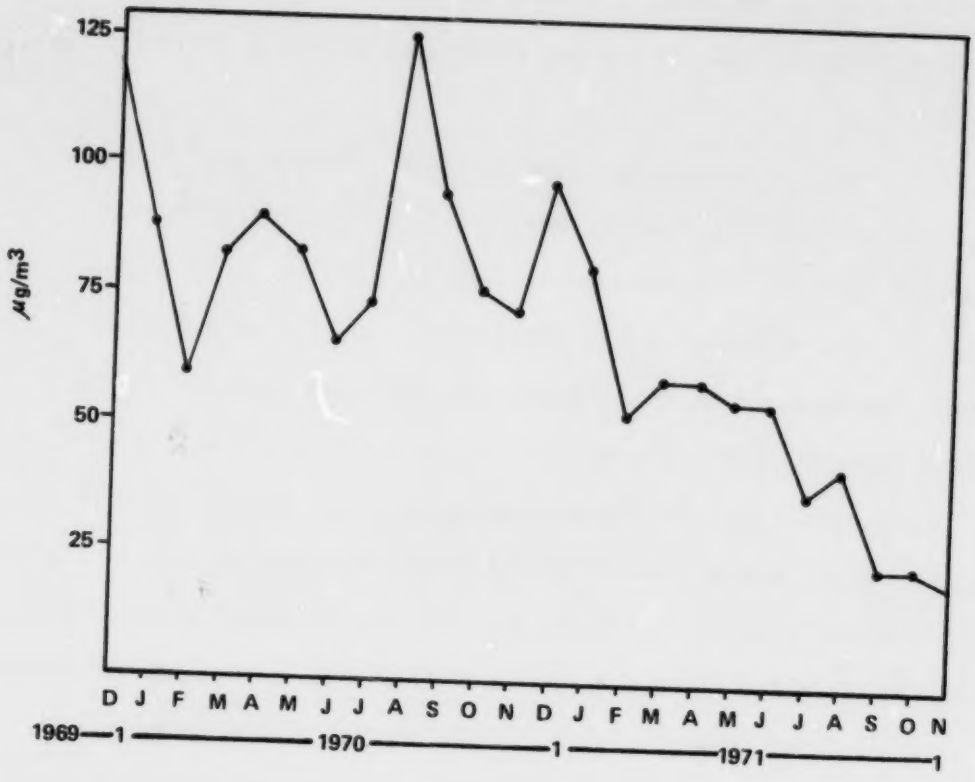


Figure 13 shows a consistent decrease in levels recorded over a two year period at the EPA CAMP station. Data presented in Tables 15 and 16 do not appear to collaborate these observations, but longer periods would have to be compared. It would be expected that SO_2 levels would be dropping, due to a trend toward increased use of low-sulfur fuels.

C. Phase II Pollutants. Monitoring of Phase II pollutants, e.g., carbon monoxide, hydrocarbons, nitrogen dioxide, and photochemical oxidants, is conducted at stations located in St. Louis City, St. Louis County, and in the Illinois portion of the study area. For purposes of this report, only the most recently available data from most of the stations located in the City and County of St. Louis, including the EPA monitoring station, were utilized in describing the ambient levels of the primarily motor vehicle generated pollutants. The ready availability of more data for this analysis was primarily due to differences in data formatting techniques and the lag time between the initial collection of the data and their subsequent reduction and analyses. In any event, the data presented here should adequately portray the ambient levels of these pollutants in the St. Louis metropolitan area.

A summary of the basic data is presented in Tables 15 and 16. Quarterly average and maximum concentrations for the calendar year 1971 and the third quarter of 1972 for the St. Louis County stations and the EPA monitoring stations are located in Table 15. (The third quarter data were made available earlier because of a special moni-

toring program conducted during the summer of 1972.) Similar information for the City of St. Louis stations, but only for the third quarter of 1972, is detailed in Table 16. Averaging times used are one hour for carbon monoxide, oxidants (ozone), and hydrocarbons and 24 hours for nitrogen dioxide, except at the EPA station which reports one hour NO_2 averages. It should be noted that stations numbered 9 and 10 in this section of the report correspond to numbers 5 and 4, respectively, in the initial assessment of SO_2 and TSP.

Oxidant. A comparison of the oxidant levels recorded in St. Louis County and at the EPA station (M-1) during 1971 show that the average levels of oxidant are relatively uniform throughout the area. In 1971, all of the stations considered fall within the range of annual averages of 24 to 31 $\mu g/m^3$. Although to a lesser degree, this is also the case when the quarterly averages are compared. This is to be expected since oxidants are generated by atmospheric reactions and, thus, are not directly influenced by nearby pollution sources. A comparison of the City and County data for 1972 show that the levels in the City are of a similar nature.

The oxidant levels exhibit a rather strong seasonal influence. Because of the importance of solar radiation in the formation of photochemical oxidants, their levels are generally higher in the summer and to a lesser degree in the spring and fall seasons. During 1971, the average oxidant levels were in the range of 10-20 $\mu g/m^3$ during the first quarter (January-March) rising to

33-40 $\mu g/m^3$ during the third quarter. Similarly, the highest maximum concentrations occurred during the third quarter.

The observed concentrations show that the St. Louis area has a substantial photochemical oxidant problem. During 1971, the national ambient air quality standard of 160 $\mu g/m^3$ was exceeded 64 times at station #6, 39 times at station #7, 17 times at station #8, and 17 times at station #9. The above statistics only represent the St. Louis County portion of the study area.

Carbon Monoxide. The concentration patterns of carbon monoxide follow very closely the traffic patterns of the area. The highest concentrations are observed in the most heavily travelled portions of the City. The annual average concentrations of CO varied from a high of 5.1 mg/m^3 in the center of St. Louis to 2.9 mg/m^3 in the suburbs. This comparison does not include the City of St. Louis stations.

The highest concentration of CO recorded during the period of record was 38 mg/m^3, which occurred in the center of St. Louis during the fourth quarter of 1971. Although data were not available to compare the observed concentration with the eight-hour air quality standard (10 mg/m^3, not to be exceeded by more than once per year), none of the observed levels exceeded the one-hour standard of 40 mg/m^3.

Hydrocarbons. Because of problems with instrumentation, only limited data were available on the ambient levels of hydrocarbons. The problem is compounded since data are limited to total hydro-

carbons, which includes considerable amounts of naturally occurring methane. Although methane measurements are routinely made at the EPA station, these data were not included because analysis of the data indicated some instrument malfunction.

The available information on the levels of total hydrocarbons shows a range of average quarterly concentrations of 460 $\mu g/m^3$ to 2750 $\mu g/m^3$. The maximum concentration observed during the third quarter of 1972 was 8,200 $\mu g/m^3$ which was recorded at station #10 in St. Louis County.

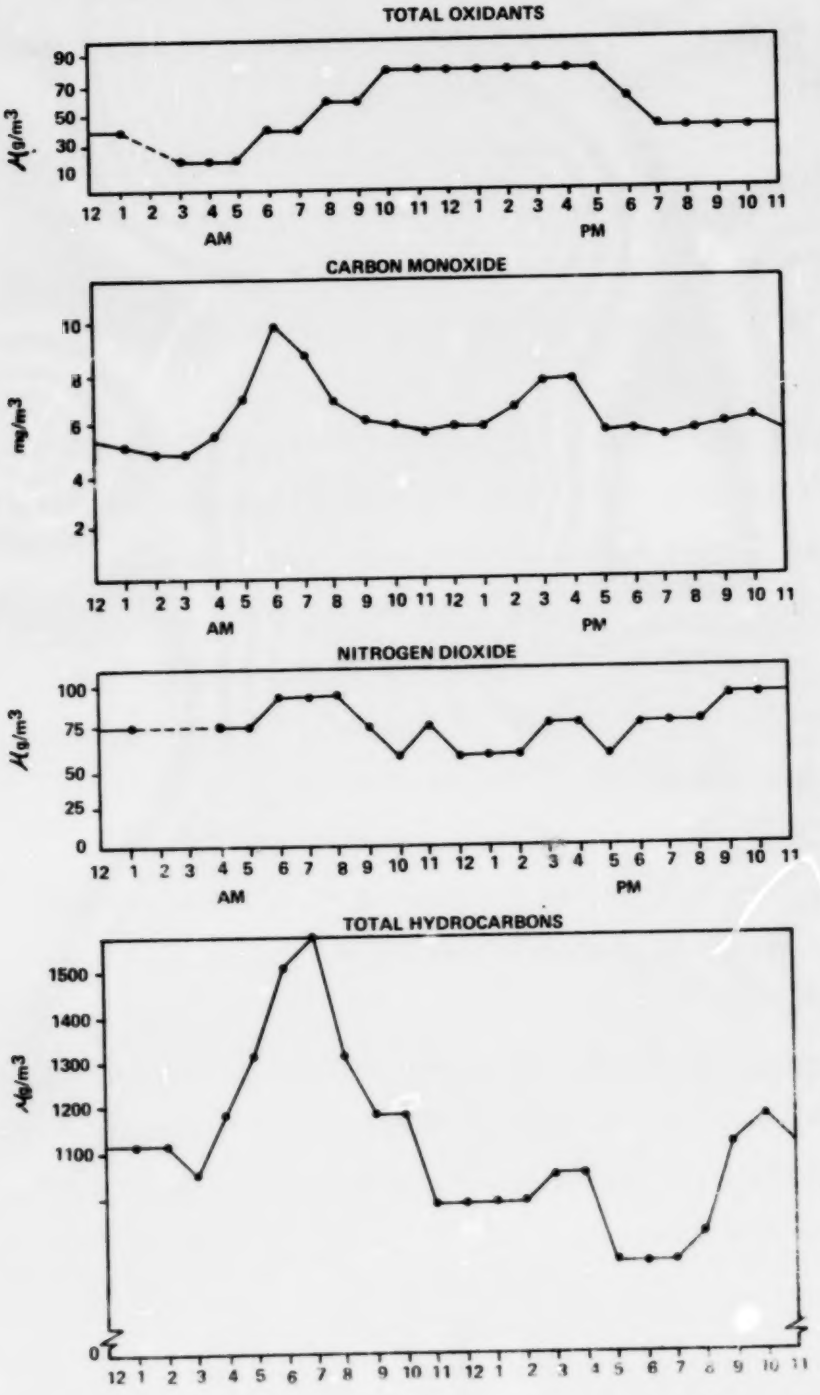
Nitrogen Dioxide. The methods for measuring nitrogen dioxide are presently undergoing a thorough testing and evaluation program. Until these studies are completed, extreme caution must be exercised in interpreting and using the NO_2 data.

The average NO_2 levels recorded in the St. Louis area show a range for 1971 of 58 $\mu g/m^3$ to 92 $\mu g/m^3$. These values are consistent with the concentrations observed during the third quarter of 1972. The U. S. ambient air quality standard of 100 $\mu g/m^3$ as an annual average was not shown to be exceeded. However, more data is needed to adequately evaluate the NO_2 problem of the region.

Diurnal Variation. The manner in which the concentrations of these pollutants vary during a 24-hour period is illustrated in Figure 14 where the average hourly concentrations for July 1971 at a selected station are shown.

FIGURE 14

DIURNAL VARIATIONS IN POLLUTANT CONCENTRATIONS MEASURED AT EPA CAMP STATION, JULY 1971



The curve for carbon monoxide shows typical peaks at about 6:00 a.m. and 3-4:00 p.m. corresponding to morning and afternoon heavy traffic periods. Carbon monoxide concentrations are highly source-dependent since most of the CO emissions are from automobiles in the St. Louis study area.

Nitrogen oxide concentrations exhibit smaller peaks in the morning, mid-afternoon, and late evening. The smaller peaks and increases in concentration in late evening can be explained by the fact that only 27 percent of the NO_2 emissions are produced by transportation sources and that as the photochemical reaction slows in the evening less NO_2 is taken out of the atmosphere, contributing to the increased concentration.

Diurnal concentrations of hydrocarbons show a peak at 7:00 a.m. with levels dropping sharply thereafter. (After 8:00 p.m. hydrocarbon levels begin to rise again.) This can be at least partially explained by the stronger inversion in the morning and photochemical reactions taking hydrocarbons out of the air in the afternoon.

Oxidant levels are shown to rise slowly during the morning reaching a peak at 10:00 p.m., remaining constant until 5:00 p.m., and dropping rapidly after that time. This change in oxidant levels correlates with what is known about the photochemical reaction, that it is time and sunlight dependent.

METEOROLOGICAL MEASUREMENTS

I. Introduction

Information on the movement of air masses within a study area is essential to the correct assessment of the air pollution problem. In the St. Louis area, meteorological information is obtained from a meteorological station located at the municipal airport, Lambert Field, supplemented by certain meteorological measurements made at the comprehensive air monitoring stations. The measurements made at these stations consist of wind speed, wind direction, and temperature. In the case of the City of St. Louis and the County of St. Louis stations, these sensors are linked by the telemetry system.

For purposes of validating the diffusion model for predicting SO_2 and suspended particulate concentrations, the meteorological data were taken from the measurements made at Lambert Field. Climatological information was collected for the five-year period from 1964-1968 and, in order to calibrate the climatological dispersion model, data was also collected for the winter of 1970-1971.

Topography in St. Louis is essentially level so that measurements taken at the airport should provide data reflecting weather conditions of the City. Most of the data were obtained from the National Climate Center in Asheville, North Carolina, where meteorological information for the United States is processed and stored. This City has already seen several previous air pollution studies so

that adequate meteorological observations were available, making it unnecessary to establish additional meteorological instrumentation.

II. Average Meteorological Conditions

A. Wind Flows. Due to level terrain and high storm frequency, wind flow in St. Louis is moderate with the medium wind speed range being 7-10 mph (Table 17).

TABLE 17 PERCENTAGE OF OCCURRENCE OF WIND SPEED RANGE FOR ST. LOUIS.

Range (mph)	Percent
0-3	9.6
4-6	23.8
7-10	37.9
11-16	25.3
17-21	2.9
> 21	0.5

Seasonal and annual wind rose data averaged for the period 1964 to 1968 are presented in Figure 15. Two sectors have the greatest frequency of winds, the south and the west to west-northwest. The highest frequency of southerly winds are seen in summer with the highest frequency of west to west-northwest winds occurring in the winter.

B. Mixing Height. No upper air data for St. Louis were available for the period 1964 to 1968. Therefore, it was necessary to interpolate the mixing height values from the two neighboring rawindsonde stations, Peoria, Illinois, and Columbia, Missouri.

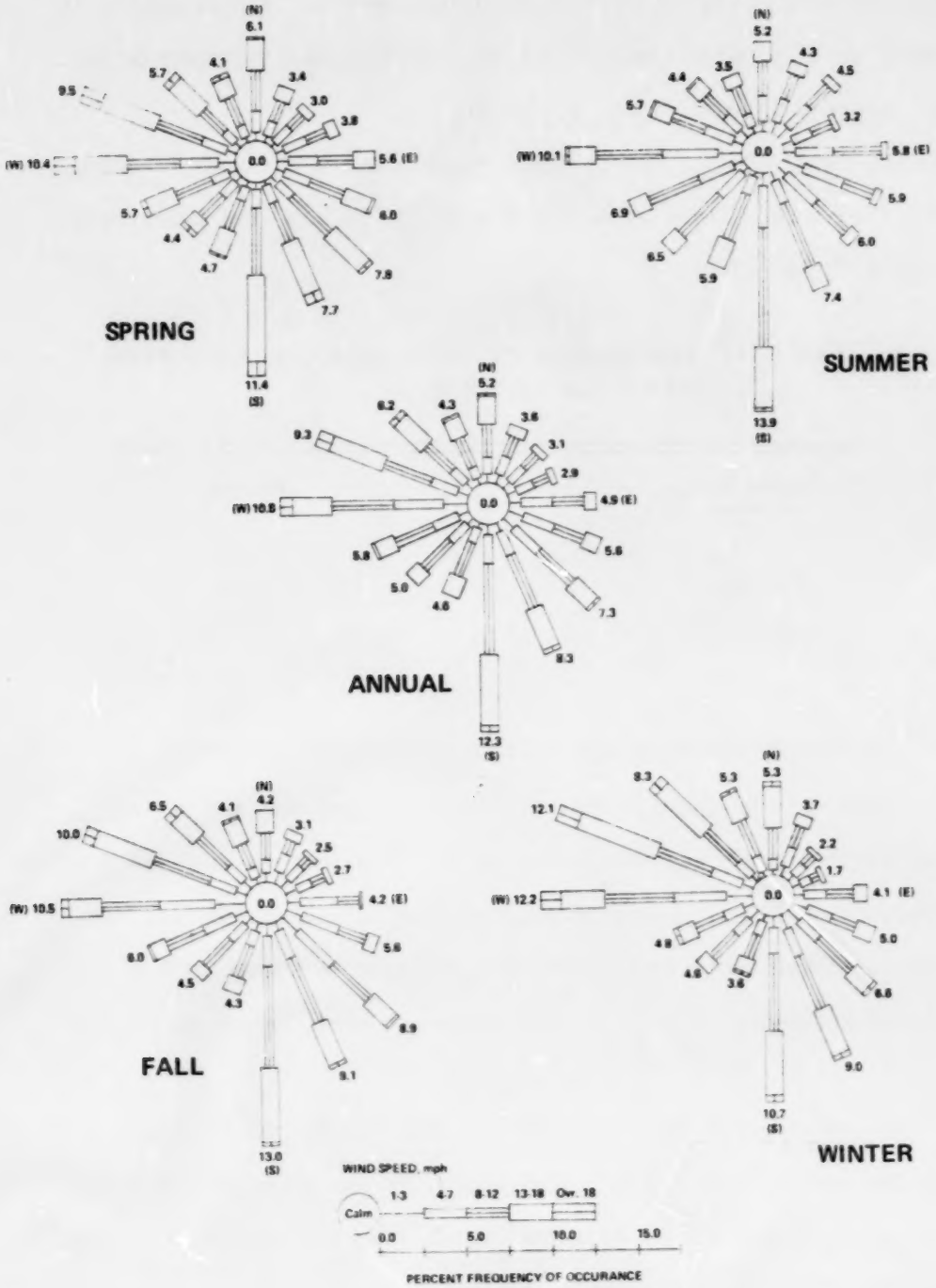


FIGURE 15 Wind Roses for St. Louis, 1964 - 68.

Ventilation is defined as the product of mixing height and transport wind speed and is used in the measurement of pollution potential. This simple concept of ventilation, however, does not explain completely air pollution potential. St. Louis receives a great amount of precipitation due to a frequent number of days with active weather systems. This is caused by extratropical cyclones in winter and convertive storms in summer. Furthermore, wind speeds in the critical surface layer are strong, partly because of smooth topography and frequent storm activity. All of these additional factors contribute to a lessening of the potential.

C. Relative Frequency of Wind Speed, Direction, and Stability. The annual relative frequency of wind speed, direction, and atmospheric stability were obtained from the records of Lambert Field, Missouri, and processed using a revised version of the usually called Star computer program at the National Climate Center in Asheville, North Carolina. Data similar to this are used in the operation of the climatological dispersion model in order to compute average annual and seasonal mean concentrations of air quality.

D. Temperature. A summary of average temperature by month is given in Table 18.

TABLE 18 AVERAGE MONTHLY TEMPERATURE (°C)

Jan.	-0.6	Apr.	13.5	July	25.5	Oct.	13.1
Feb.	0.1	May	18.2	Aug.	23.9	Nov.	7.5
Mar.	6.3	June	23.7	Sept.	19.7	Dec.	1.6

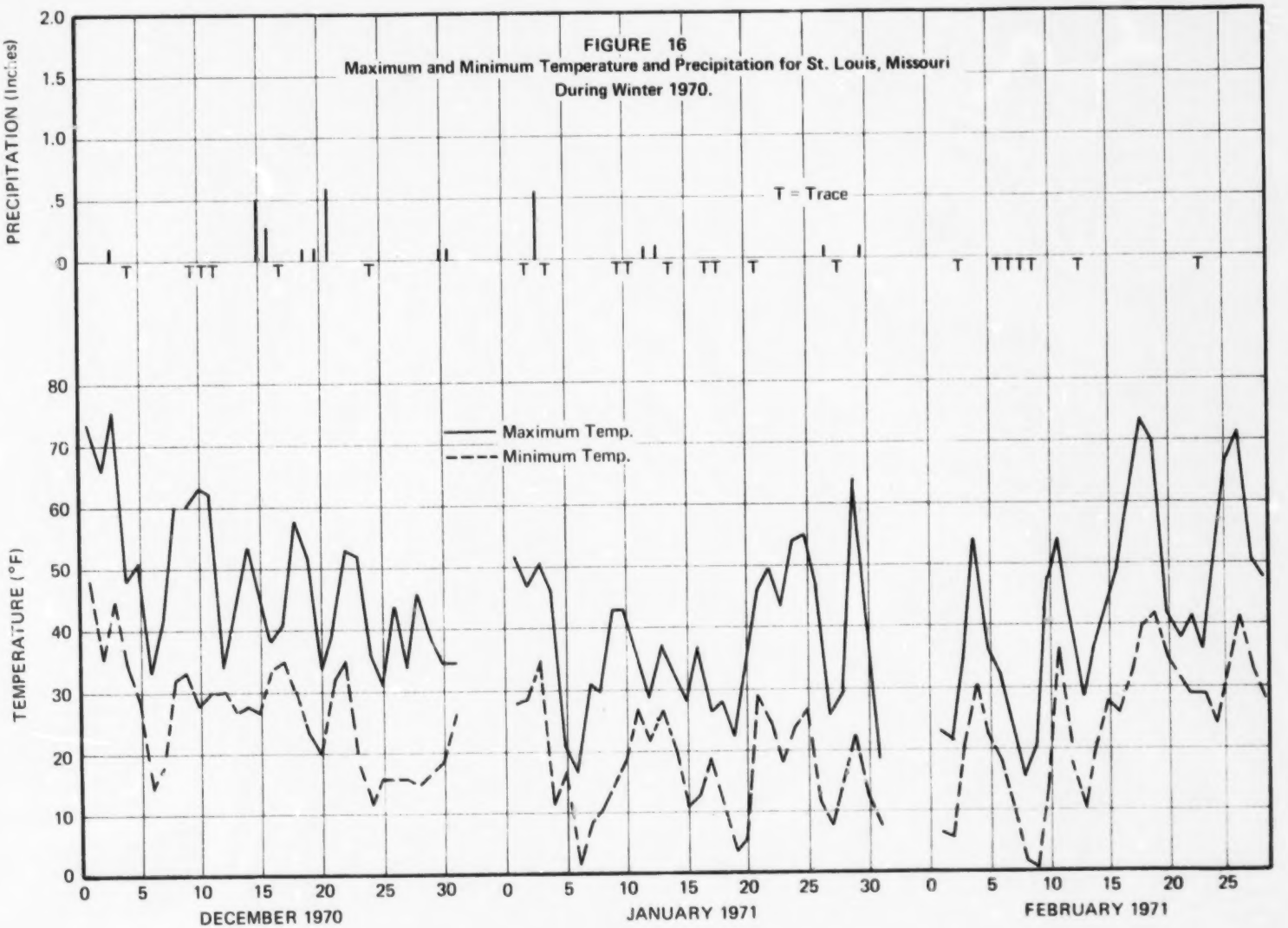
III. Comparison with Meteorological Measurements of Winter, 1970-1971

Comparison of average data for the five-year climatological period and data of winter 1970 shows a close similarity between these data. Temperatures during January 1970 (Figure 16), were somewhat lower than the mean, but for the entire period no sharp differences are seen

The main features of the winter 1970 wind rose are also similar to the five-year mean wind rose data (Figure 17).

Only the winter 1970 precipitation pattern appears at variance from the five-year mean curves. While December had the normal two inches of precipitation, January and February 1970 had much less rainfall than the two to three inches observed on the average.

FIGURE 16
Maximum and Minimum Temperature and Precipitation for St. Louis, Missouri
During Winter 1970.



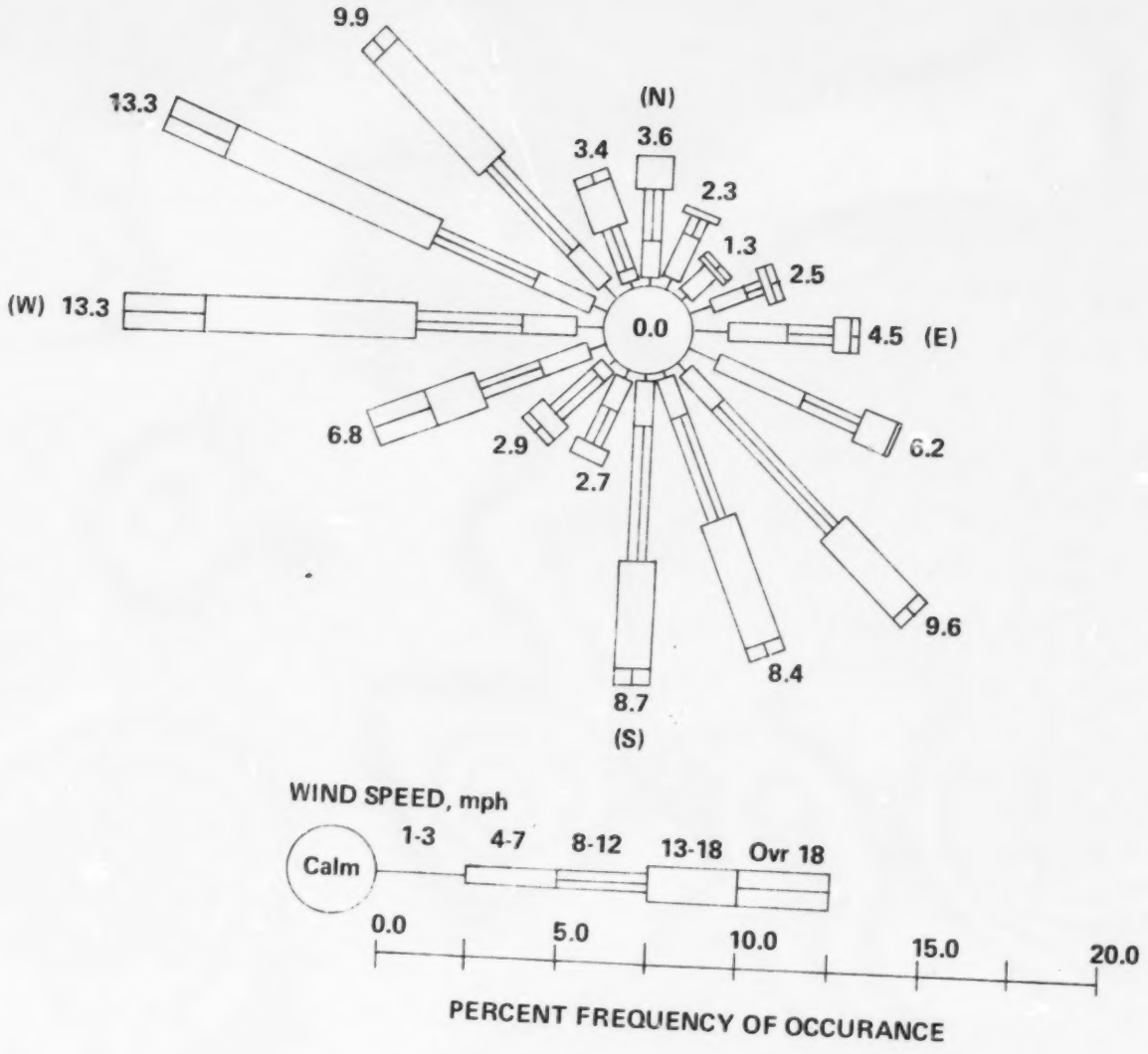


FIGURE 17 Winter, 1970, Wind Rose for St. Louis

PROJECTIONS OF EMISSIONS

I. Introduction

Long-term forecasts of air quality are essential in the formulation of control requirements and strategies. The development of such forecasts requires the estimation of anticipated air pollutant emissions and the translation of these emission estimates into ambient concentrations through the use of diffusion modeling. This section of the report outlines the forecasting of emissions for the St. Louis area to the year 1990.

The estimation of future emissions requires the use of various indicators that relate to the anticipated development of the area under study. These indicators, such as expected population growth, industrial and business activity indices, and trends in motor vehicle travel, have been developed for other purposes and are generally available for metropolitan regions.

Such growth factors were obtained for the St. Louis area and were applied to the 1969 inventory. These factors provided the basis for the projections. In addition, various forecasts relating to expected sulfur contents of fuels, efficiencies of control equipment, and the like were considered in developing the final emission rates. These forecasts were based on current and proposed legislation and regulations.

Predicting where new sources will locate is a major problem in estimating future emissions. Adequate estimates of area totals can be obtained, such as population or industrial activity, but the areas of future development are not clearly defined. Because of this, these projections must be viewed as being the best available at the time they were made, but need to be revised as new information becomes available.

II. Expected Growth and Development

For the St. Louis area, data on population growth and density have been developed by the East-West Gateway Coordinating Council. Forecasts of industrial activity had been previously made by the Department of Commerce under contract to EPA. In addition, general forecasts of solid waste disposal and expected fuel and travel patterns had been compiled by various municipal and State organizations.

Projections of population made by the East-West Gateway Coordinating Council (EWGCC) show an increase from nearly 2,400,000 people in 1970 to 3,690,000 in 1990, an increase of 48 percent. As shown in Figure 18 the most significant increases are forecast for St. Louis and St. Clair Counties.

The expected level of various industrial and commercial activities is shown in Table 19. The activity level is expressed as an index with 1967 being the base year. As can be seen, large increases are predicted for chemicals, machinery, and manufacturing, whereas slower rates of activity increases are predicted for food products and petroleum.

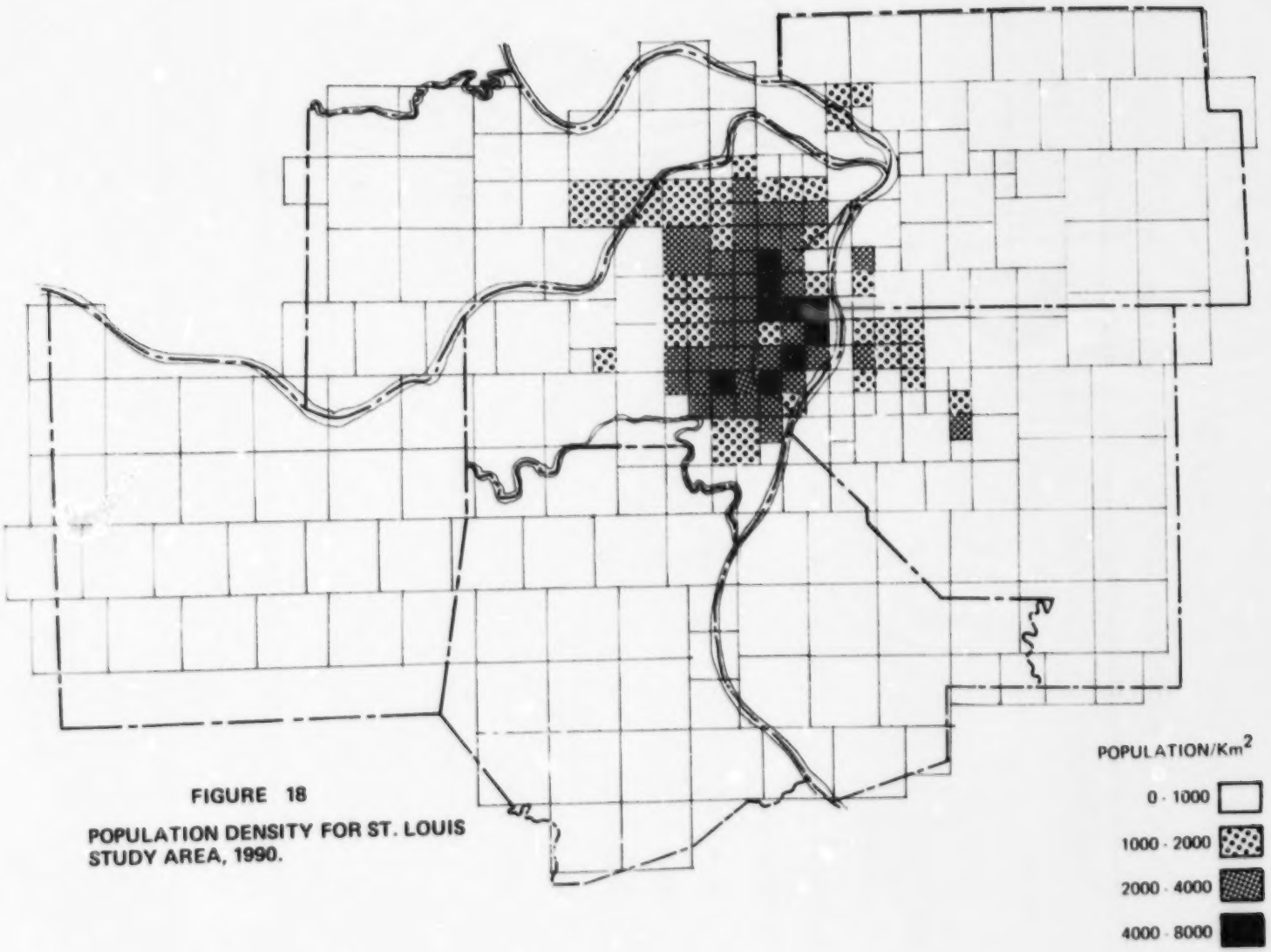


FIGURE 18

POPULATION DENSITY FOR ST. LOUIS STUDY AREA, 1990.

TABLE 19

INDUSTRIAL PROJECTIONS FOR ST. LOUIS STUDY AREA

Industry Category	1970[1]	1980[1]	1990	1990/1970
Manufacturing	111	158	210	1.90
Mining	103	136	170	1.65
Food Prod.	101	121	132	1.31
Textiles	106	137	170	1.60
Chemicals	117	179	240	2.04
Machinery	109	164	220	2.01
Paper	105	150	200	1.90
Petroleum	129	150	170	1.32
Prim Metals	109	140	175	1.60
Stone, Clay, Glass	113	163	220	1.95
Air Transportation	108	133	170	1.58
Water Transportation	111	151	200	1.80

1967 = 100

[1] Source: "Economic Projections for AQCR", A report to NAPCA by USDC, OBE, RED, June 1970

Expected travel demand and density has been estimated by the East-West Gateway Coordinating Council on the basis of a comprehensive transportation study. The projections of air and water vehicles were made based on the USDC report.

III. Procedure for Calculating Emissions

Projections of emissions were made by applying the growth factors derived from the aforementioned references to the base year inventory. For stationary sources, the following assumptions were used in making the projections.

1. An overall increase of 50 percent in the residential space heating requirements is forecast. All new units will be heated by fuel oil or natural gas. The use of coal as a residential fuel will be eliminated completely.

2. An overall increase of 50 percent in the fuel requirements for commercial uses is forecast. The use of coal will be eliminated and all new units will be heated by fuel oil or natural gas.

3. The total industrial fuel usage will increase in proportion to the anticipated industrial growth of 80 percent. The use of coal will remain approximately at current levels. The types of fuels used in industrial point sources will remain essentially unchanged. Increases are determined by the USDC report.

4. The generation of electricity will double every ten years with coal remaining as the predominant fuel. Nuclear plants will not be in operation until 1985. By 1990, nuclear power will serve about 15 percent of the demand.

5. The sulfur content of fuels will not exceed one percent.

6. Ash content of coal will remain unchanged.

7. Particulate control devices will continue to be added and improved. For steam-electric power plants, an overall control device efficiency of 99 percent was assumed. For industrial sources, a 90 percent control level was used.

Transportation source emission projections were based on the following assumptions:

1. Motor vehicle travel is estimated to increase about 66 percent. This is a slightly faster rate than the population growth of the region.

2. Federal exhaust emission standards will be met.

3. Railroad operations will increase by about 50 percent over the 20-year period. This was based on extrapolation of historical data from the U. S. Bureau of Mines.

4. River traffic will nearly double by 1990. This is based on data from the USDC economic projections and U. S. Bureau of Mines' historical data.

5. Aircraft activity is estimated to increase by about 60 percent over the 1969 levels.

The per capita generation of solid waste is assumed to increase to 6.8 kg (15 lb)/day. (In 1969, the generation rate was about 4.5 kg/person per day.) It was estimated by the various agencies that nearly 85 percent of the waste would be disposed in sanitary landfills

with the rest being burned in either on-site or municipal incinerators. New municipal incinerators are not planned. Open burning of waste material is expected to be negligible (less than 0.5 percent). This is mostly on-site disposal of leaves, agricultural waste, and some household waste.

Expected industrial activity was estimated from the USDC report on economic projections. Various activity indicators were applied to the base year inventory to yield an estimate of conditions in 1990. It was assumed that sources with existing pollution control devices would upgrade or add to them. An overall collection efficiency of about 50 percent was assumed for those sources which are currently uncontrolled.

It is important to note that many of the assumptions made here may be subject to question. The most notable of these are the assumptions relating to the projected use of only coal in power generating stations, the extensive use of landfills for refuse disposal and the expected maximum sulfur content in 1990. Plans are being made to convert some power station boilers to oil-fired units. Also, there is a distinct possibility that considerable amounts of refuse may in the future be disposed of by burning in power generating stations. Whatever the case, the availability of a working diffusion model allows the evaluation of the expected air pollution levels for many selected or assumed alternatives.

IV. Results

The projected 1990 emissions are summarized by source category in Table 20. The most notable changes (as shown by these projections) are substantial reductions in the amounts of carbon monoxide, hydrocarbons, and oxides of nitrogen emitted by motor vehicles.

Table 21 shows a comparison between 1990 and present total emissions. Sulfur oxides are predicted to increase by 9 percent and particulates are predicted to decrease 36 percent. Large decreases are projected for CO and HC due to road vehicle exhaust standards implemented by the Federal Government. An increase of 77 percent in NO_x is forecast due to a four fold increase in power plant coal consumption without NO_x controls and a counteracting control on automobile exhaust as implemented by Federal Standards.

The emission estimates for stationary fuel combustion were based on the expectation that the 1990 energy demands will be met through the use of approximately 33 million tons of coal, 2,400 million liters of fuel oil, and 11 billion cubic meters of natural gas, as shown in Table 22.

As estimated 4.9 million tons of gasoline and 340,000 tons of diesel fuel is expected to be consumed by motor vehicles in 1990. This was based on expected average per capita travel needs for the United States. Emissions of SO_x and particulates from this category, 3,700 tons and 1,600 tons, respectively, are not large when compared to the total, but they may become significant at major intersections or during times of heavy travel. This category accounts for 83

TABLE 20

SUMMARY OF AIR POLLUTANTS IN THE ST. LOUIS STUDY AREA, 1990

(10^3 Kg/year)

Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	3,660	1,640	136,950	15,930	13,070
Other	3,000	4,560	13,200	11,200	4,600
Subtotal	6,660	6,200	150,151	27,130	17,670
Stationary Fuel Combustion					
Industry	68,900	37,500	3,180	5,410	47,500
Residential	2,320	1,980	1,650	740	5,660
Commercial and Institutional	1,650	780	390	220	3,120
Electric Generation	543,100	18,000	14,400	4,290	257,300
Subtotal	615,970	58,260	19,620	10,660	313,580
Refuse Disposal					
Incineration	1,050	2,500	5,640	1,870	1,950
Open Burning	20	360	1,930	680	140
Subtotal	1,070	2,860	7,570	2,550	2,090
Industrial Processes	116,400	37,400	3,870	23,600	2,100
Evaporative Losses	--	--	--	21,200	--
GRAND TOTAL *	740,000	105,000	181,000	85,000	335,000

* rounded

TABLE 21

COMPARISON OF 1969 AND 1990 AIR POLLUTANT EMISSIONS
ST. LOUIS STUDY AREA

Pollutant	Emissions (10^3 kg/yr.)		Percentage change
	1969	1990	(1969 – base)
SO_x	674,000	740,000	9
Particulates	167,000	105,000	−37
CO	855,000	181,000	−79
HC	191,000	85,000	−55
NO_x	109,000	335,000	77

TABLE 22

SUMMARY OF FUEL CONSUMPTION IN THE ST. LOUIS STUDY AREA, 1990

Consumer	Coal (10^6 Kg)	Fuel Oil		Natural Gas (10^3 M^3)
		Distillate (10^6 L.)	Residential (10^6 L.)	
Residential	0	660	0	3,920
Commercial and Institutional	0	133	n	1,190
Industrial	3,210	0	1,584	5,810
Steam - Electric Utilities	28,590	0	0	0
TOTAL	32,800	793	1,584	10,920
Total Energy (10^6 cal)	194	8	16	97
Percent of Total Energy	62	2	5	31

n = negligible

percent of CO, 32 percent of HC, and 5.3 percent of NO_x emissions (Table 23).

The disposal of solid wastes are not expected to contribute significantly to the air pollution problem (Table 24). The disposal of over 9.1 million tons of waste is forecast to contribute only about 1,000 tons of SO_x, 3,000 tons of particulates, 7,500 tons of CO, 2,500 tons of HC, and 2,000 tons of NO_x, mainly in on-site incinerators.

Industrial process emissions (Table 25) are projected to account for about 116,000 tons of SO_x, 38,000 tons of particulates, 4,000 tons of CO, 24,000 tons of HC, and 2,000 tons of NO_x. These were estimated by extrapolating current emissions based on expected economic indices.

Projected emission densities for sulfur oxides and particulates matter for 1990 are shown in Figures 19 and 20, respectively.

TABLE 23

AIR POLLUTANT EMISSIONS FROM TRANSPORTATION IN THE ST. LOUIS STUDY AREA, 1990

(10^3 Kg/yr.)

Source	Activity	SOx	Particulates	CO	HC	NOx
Motor Vehicle						
Gasoline	40×10^6 v m /day	2,650	1,160	132,000	15,110	4,910
Diesel	1.1×10^6 v m /day	1,010	480	4,950	820	8,160
Vessels	20×10^6 gal diesel	360	910	540	430	620
Trains	48×10^6 gal diesel	1,440	550	1,550	1,110	1,660
Aircraft	$1,485 \times 10^3$ operations	1,200	3,090	11,140	9,660	2,300
TOTAL		6,660	6,200	150,150	27,130	17,670

TABLE 24

SOLID WASTE DISPOSAL FOR THE ST. LOUIS STUDY AREA, 1990

Disposal Method	Quantity Disposed 10^6 Kg	Emissions (10^3 Kg)				
		Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Landfill	7,730	---	---	---	---	---
Open Burning						
Dumps	0	0	0	---	---	---
On-site	45	20	360	1,930	680	140
Incineration						
Municipal	300	220	200	150	220	300
On-site	1,100	830	2,300	5,490	1,650	1,650
TOTAL	9,175	1,070	2,860	7,570	2,550	2,080

TABLE 25

SUMMARY OF INDUSTRIAL PROCESS EMISSIONS
ST. LOUIS STUDY AREA, 1990

(10^3 Kg / year)

Category	Activity Index (1967=100)	SCx	Particulate	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Grain	132	0	10,700	0	0	0
Foundries	170	0	1,900	0	30	0
Primary Smelting	175	65,400	320	0	0	0
Sulfuric Acid	240	22,000	0	0	0	0
Oil Refining	170	17,780	7,320	0	19,100	2,070
Steel Manufacturing	175	0	6,090	1,020	3,380	30
Glass Manufacturing	220	0	940	0	0	0
Cement	220	0	4,340	0	0	0
Coking	175	10,400	3,560	270	900	0
ALL OTHERS	---	850	2,660	2,580	190	0
TOTAL	---	116,400	37,830	3,870	23,600	2,100

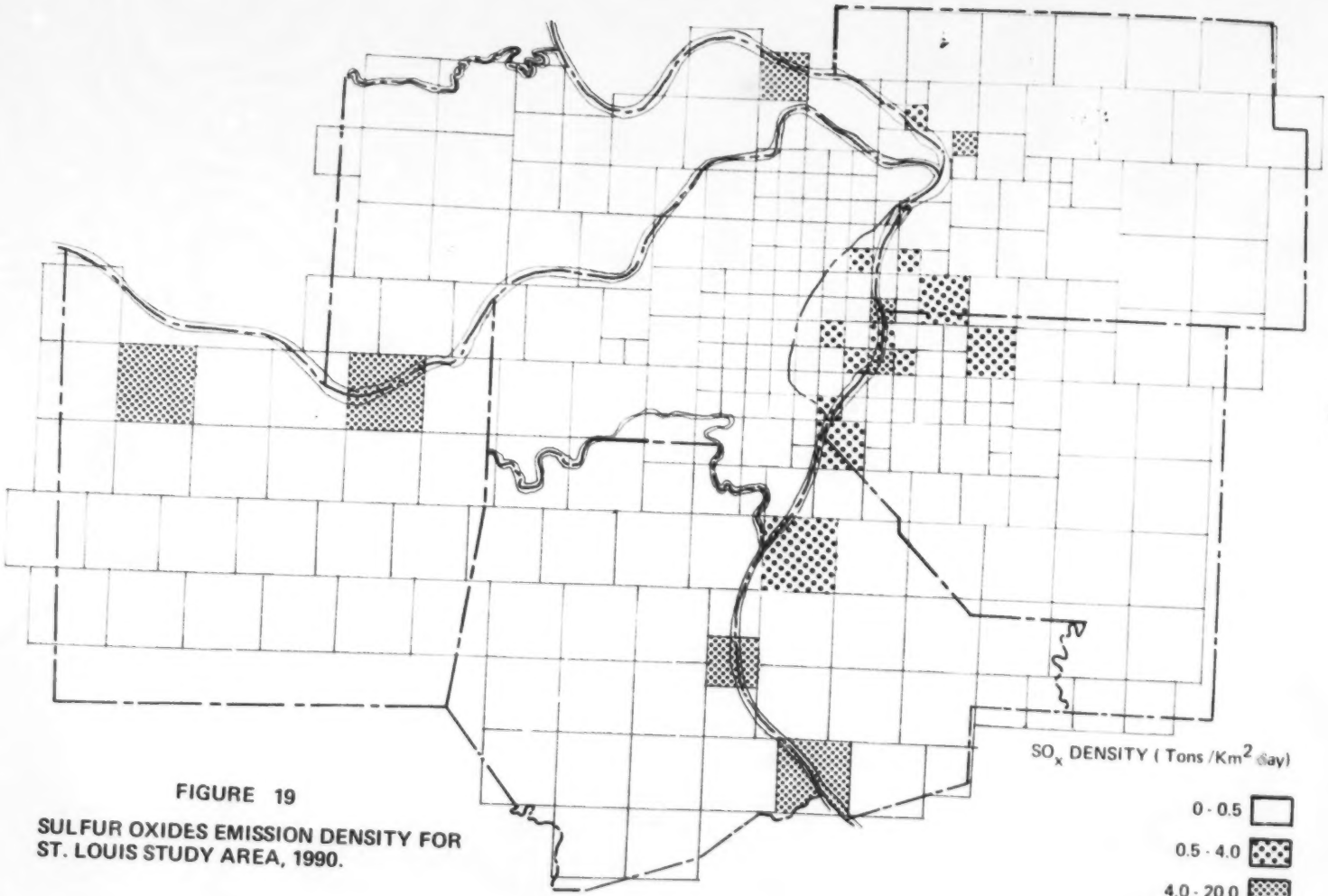


FIGURE 19

SULFUR OXIDES EMISSION DENSITY FOR ST. LOUIS STUDY AREA, 1990.

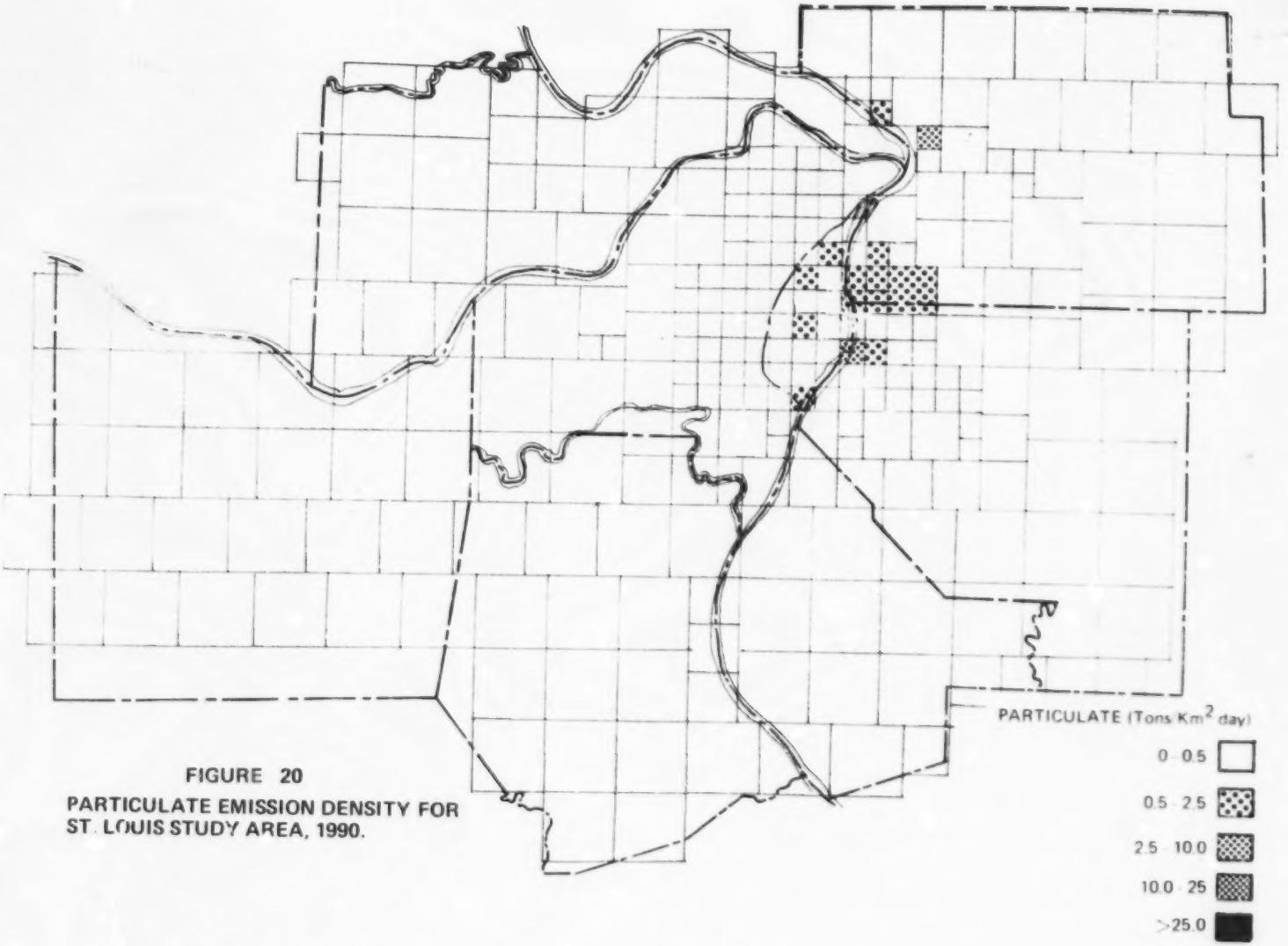


FIGURE 20
PARTICULATE EMISSION DENSITY FOR ST. LOUIS STUDY AREA, 1990.

REFERENCES

1. Forecast of Socio-Economic Characteristics for the St. Louis Metropolitan Region, East-West Gateway Coordinating Council, January 1970.

2. Economic Projections for Air Quality Control Regions, A report to NAPCA prepared by U. S. Department of Commerce, Office of Business Economics, June 1970.

3. Landsberg, H., L. L. Fischman, and J. L. Fischer. Resources in America's Future. Baltimore, Johns Hopkins University Press, 1963.

4. Union Electric Company, St. Louis, Missouri. Data obtained from Jerrel Smith.

5. Shipments of Fuel Oil. Mineral Industry Surveys, U. S. Department of Interior, Bureau of Mines, Washington, D. C., 1970.

AIR QUALITY MODELING

I. Introduction

Several air quality studies have been made in the St. Louis area. Information from these studies aided in evaluating results and making corrections to the model. This enabled results to be obtained that more nearly resembled actual conditions. Meteorological and topographical conditions in this area lend themselves well to computer simulation. Almost level terrain and brisk wind conditions are ideal for the simple climatological dispersion model that was used to predict air quality for sulfur dioxide and total suspended particulates. No modeling was attempted for the other pollutants.

II. Procedure

Concentrations of sulfur oxides and suspended particulates were calculated by the climatological dispersion model using the Gaussian dispersion function. A plot of observed versus calculated sulfur oxide concentrations during winter 1970 is presented in Figure 21. A similar plot for suspended particulates is shown in Figure 22. The computed values of mean sulfur oxide concentration fall within a factor of two of the observed values. This is also true for suspended particulates. Therefore, the linear relationships presented in Figures 21 and 22 could be used in the analysis and projection of concentrations of sulfur oxides and suspended particulates.

In a prior analysis of sulfur oxide concentrations using 1964

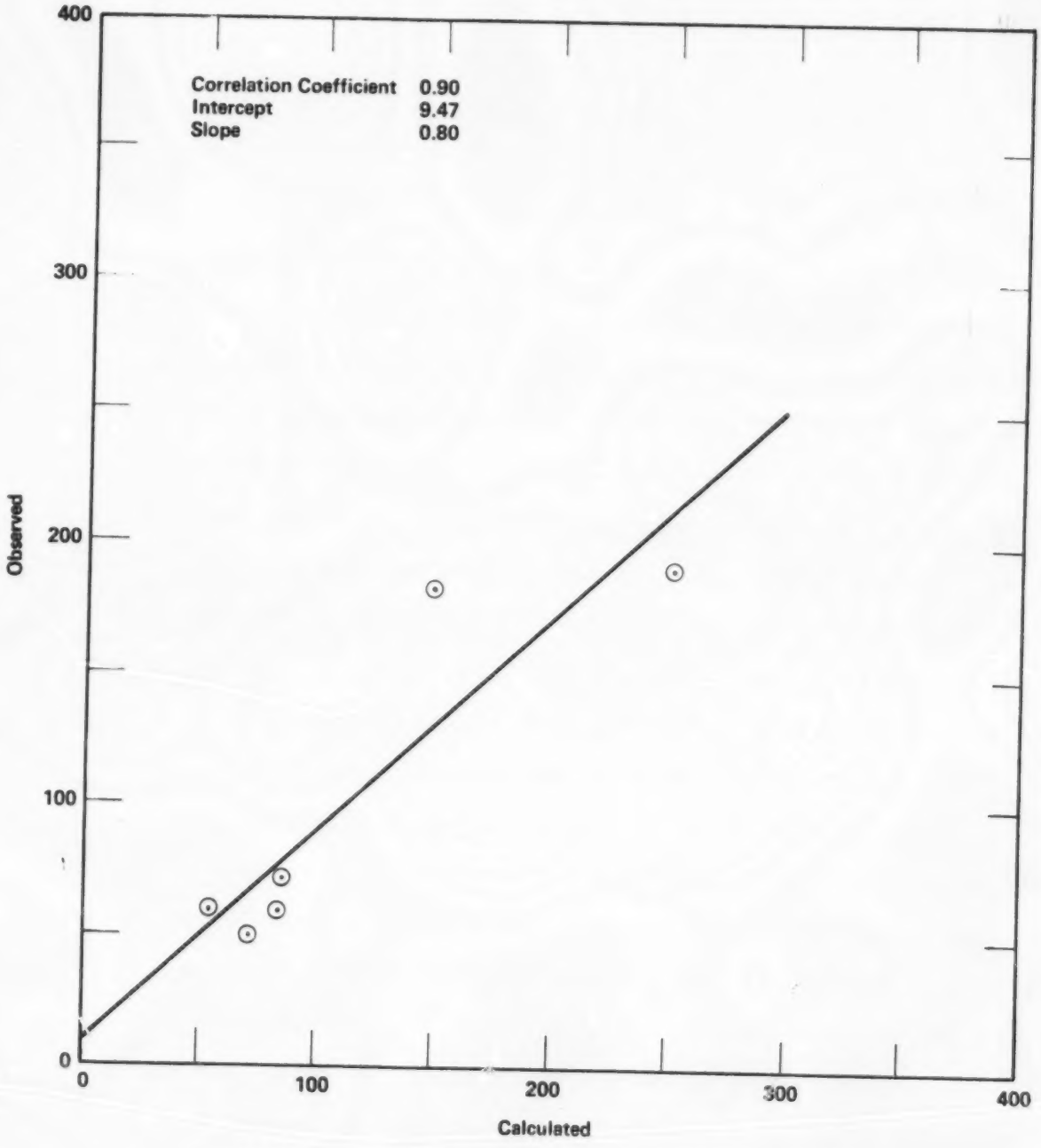


FIGURE 21 OBSERVED VERSES COMPUTED SULFUR DIOXIDE CONCENTRATIONS, WINTER, 1970.

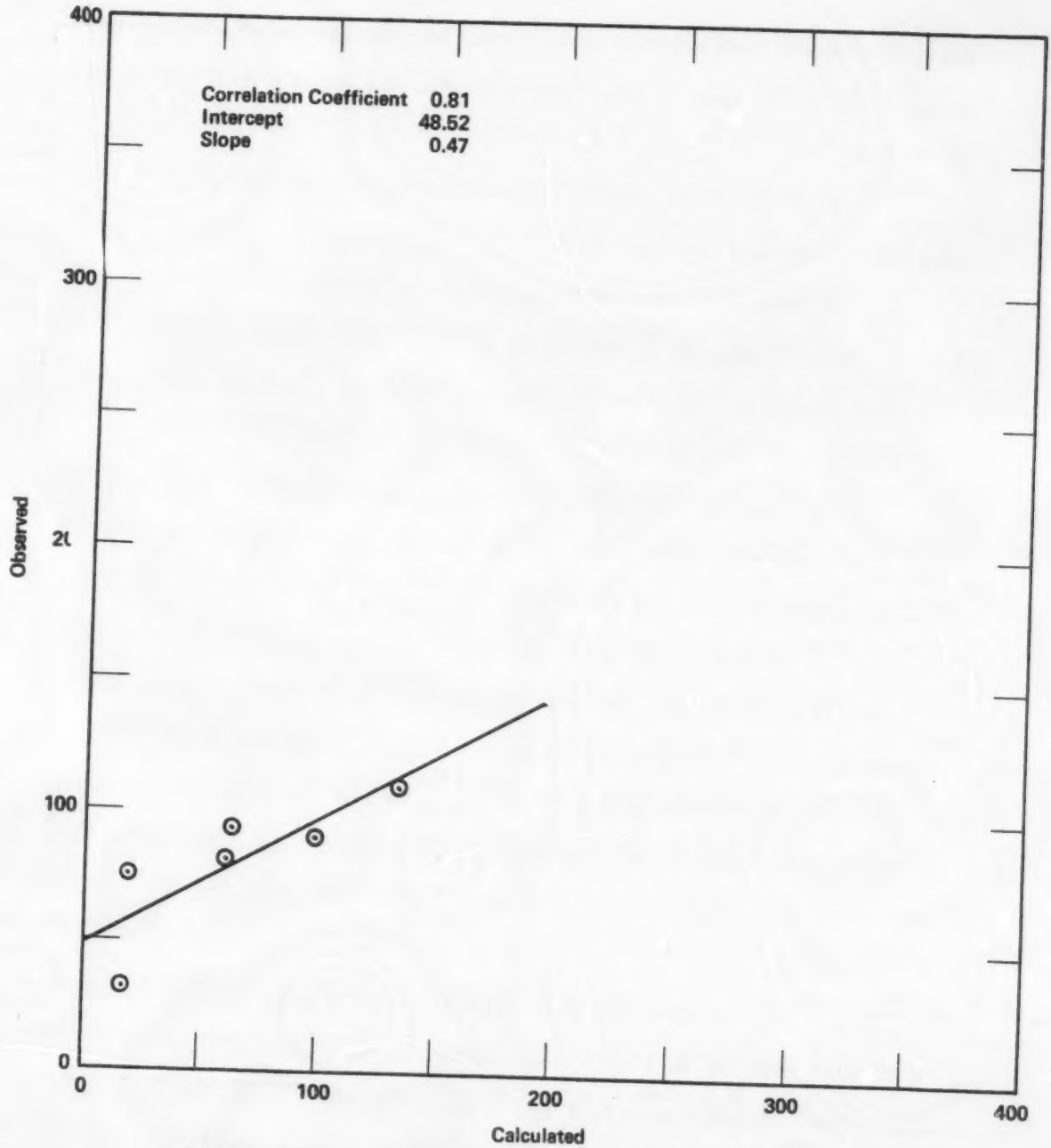


FIGURE 22 OBSERVED VERSES COMPUTED SUSPENDED PARTICULATE CONCENTRATIONS Winter, 1970.

data, the model consistently over-predicted observed values. For the present analysis, several modifications were introduced into the model as follows:

1. Plume rise: Briggs formulas replaced Holland's equation of the earlier analysis.

2. Wind profile: Extrapolated with height by power law. Earlier version assumed no variation of wind with height.

3. Emissions: Varied from day to night. Earlier version did not incorporate any daily variation.

4. Relative frequency of wind speed, wind direction, and stability separated into night and day categories. Earlier version did not separate into day and night.

5. Central wind speed of the first wind speed class increased 1.5 m/s (i.e., ten percent of the observed wind speeds are in this class). Previously a lower wind speed class was used.

Use of improved emission inventory data and the cumulative effect of the changes made in the computation techniques appear to have suppressed over-prediction by the model.

III. Results

The linear calibration relationship between observed and calculated data applied to 1970 winter, summer, and annual and projected 1990 annual concentrations of the dispersion model were found to be:

Observed = 9 + 0.8 calculated (for sulfur oxides)

and

Observed = 49 + 0.47 calculated (for particulate matter)

A. Sulfur Oxides. The predicted contours of seasonal and annual concentrations of sulfur oxides, using the current emissions inventory, outline the major electrical power, industrial, and residential air pollution sources in the St. Louis Study area (Figures 23, 24, and 25). The highest concentrations occur in the industrialized East St. Louis area during winter with a maximum value of 270 $\mu g/m^3$. The maximum summer concentration is 170 $\mu g/m^3$, and the maximum annual average concentration is 200 $\mu g/m^3$.

A major power plant to the south of St. Louis is clearly outlined on the contour maps. Concentrations around this plant are shown to be higher in the summer than in the winter. Another power plant complex located northeast of St. Louis also maintains year-round moderate sulfur oxide concentrations. Projections of sulfur oxide concentrations for 1980 (Figure 26) show the effect of pollution control devices expected to be in use by that time. Industrial process controls in use in East St. Louis should significantly reduce that area's sulfur oxide burden. However, large demands for electrical power will continue to produce high levels around generating plants.

B. Particulate Matter. Concentrations of suspended particulates do not show great seasonal variations (Figures 27, 28, and 29). The maximum winter concentration is 100 $\mu g/m^3$. Emission values remain relatively constant throughout the year resulting in the lack of seasonal variation.

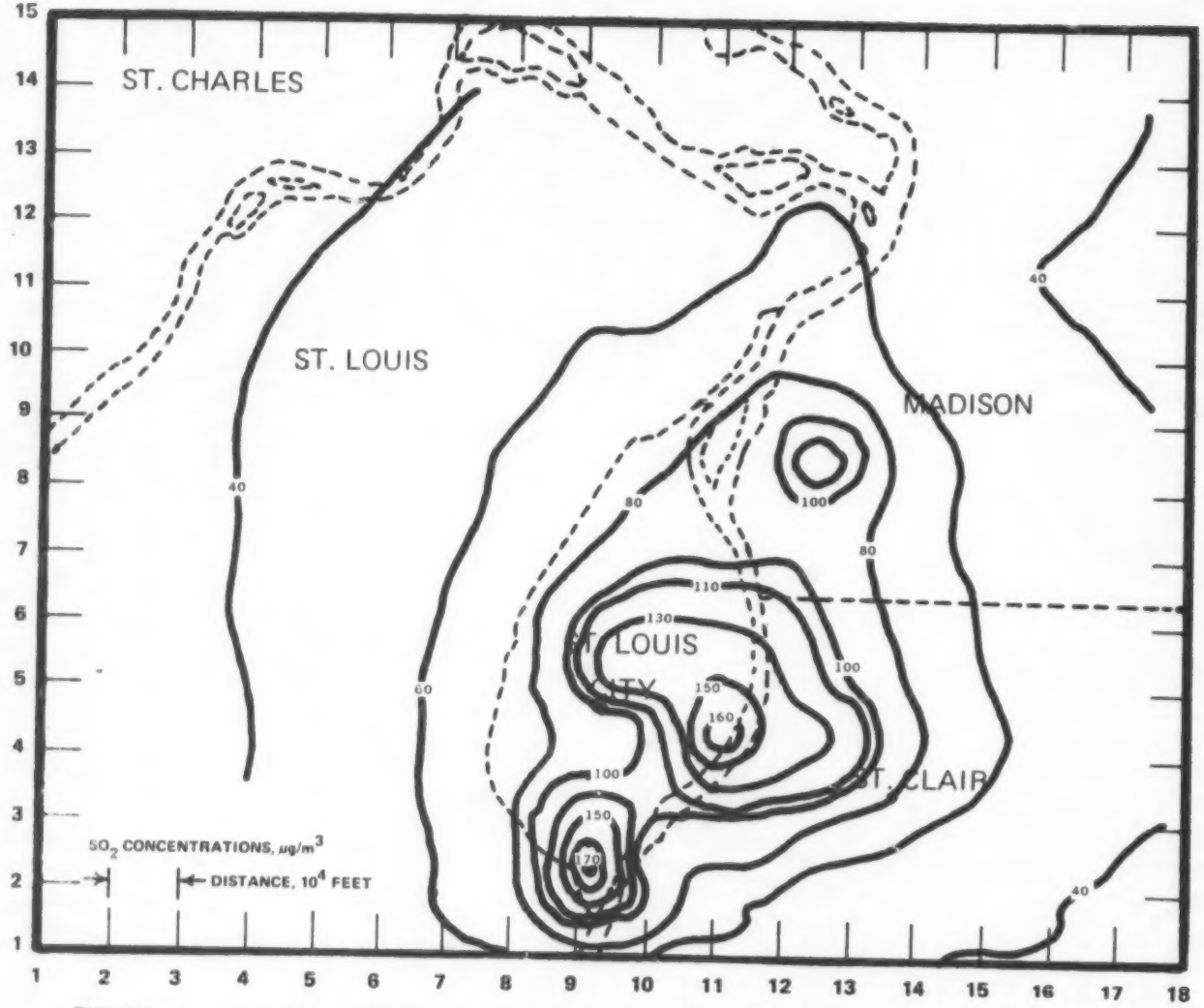


FIGURE 23 Mean Summer Sulfur Dioxide Levels in St. Louis Predicted by Model ($\mu g/m^3$).

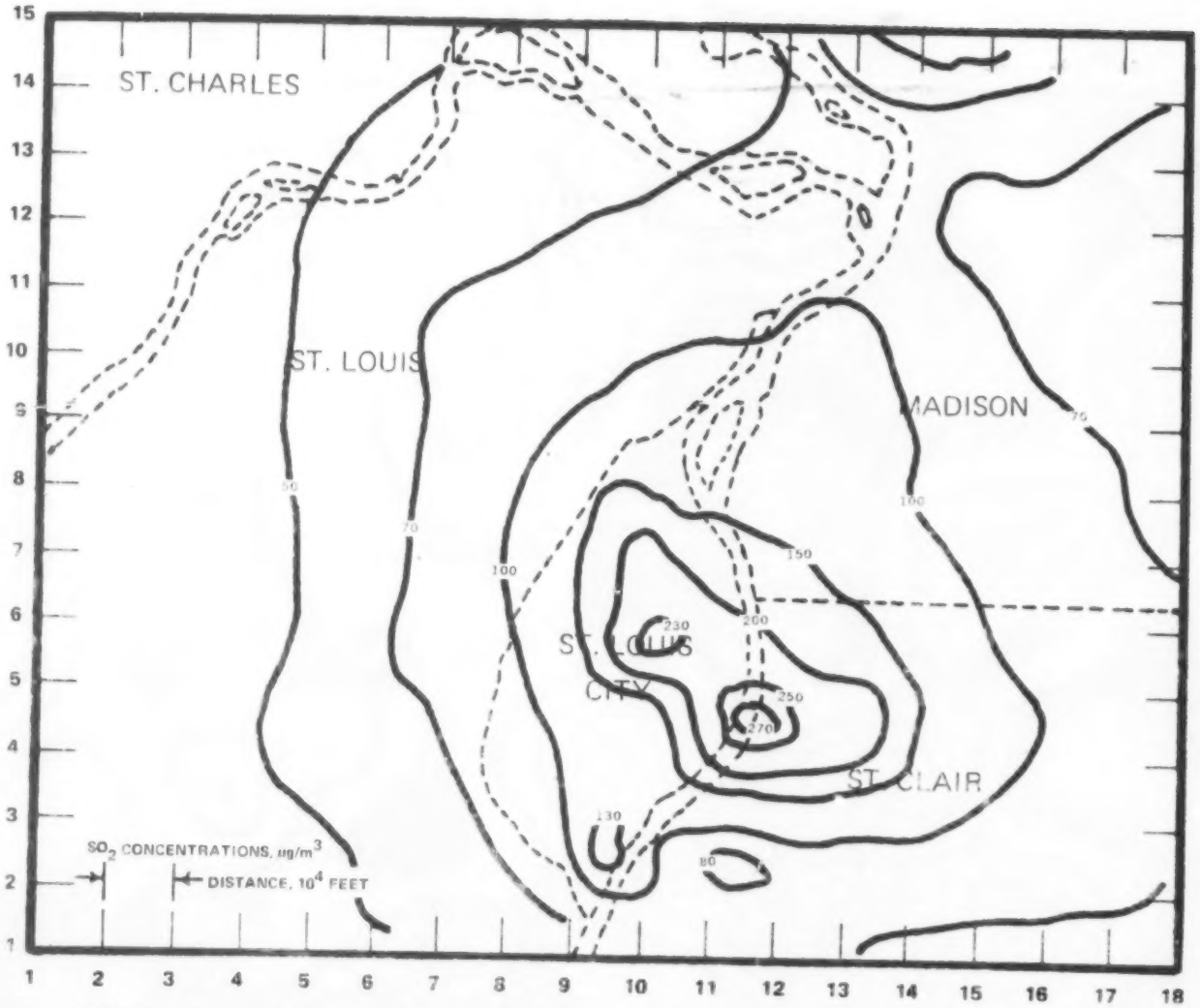


FIGURE 24 Mean Winter Sulfur Dioxide Levels in St. Louis Predicted by Model ($\mu g/m^3$).

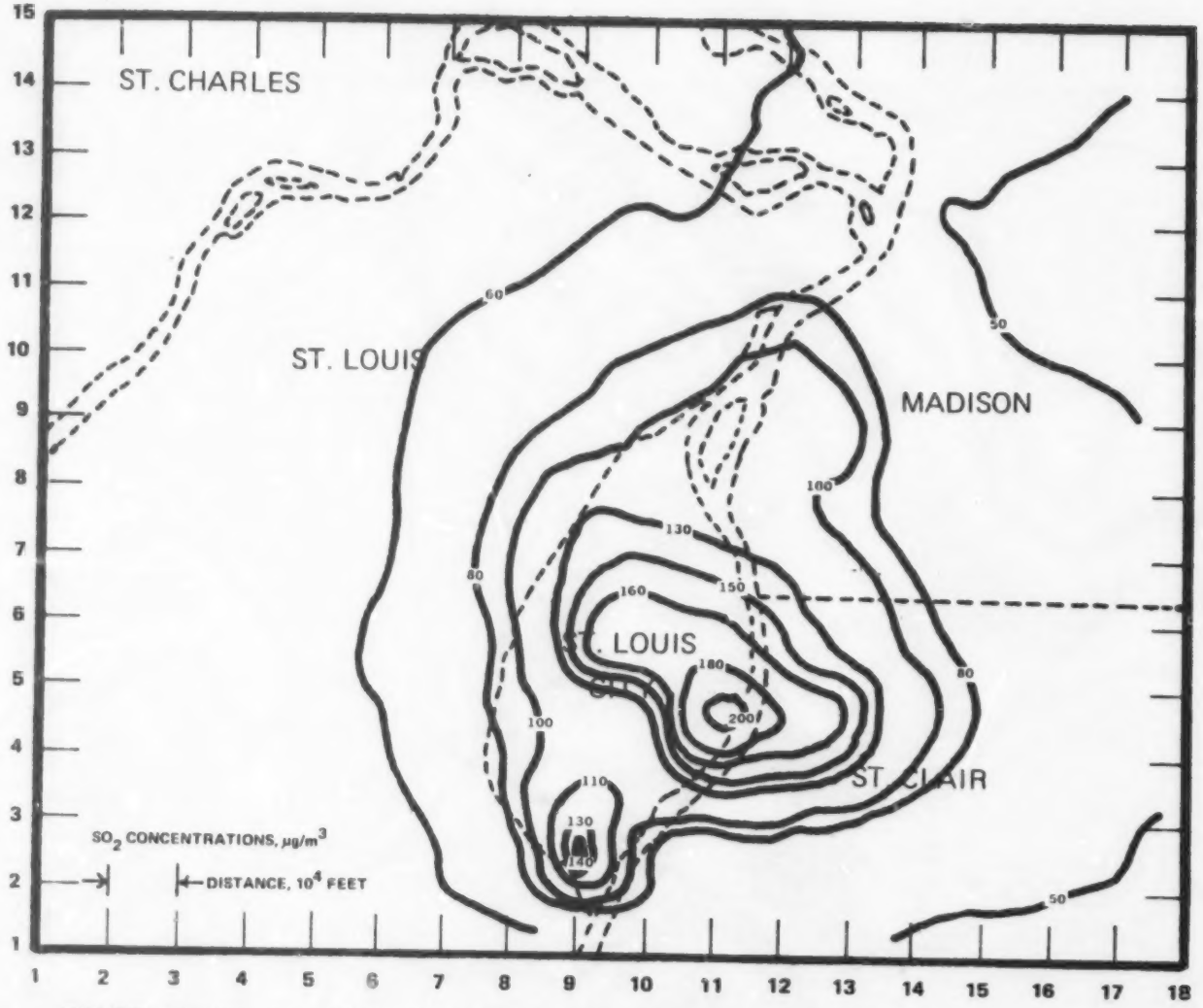


FIGURE 25 Mean Annual Sulfur Dioxide Levels in St. Louis Predicted by Model ($\mu g/m^3$).

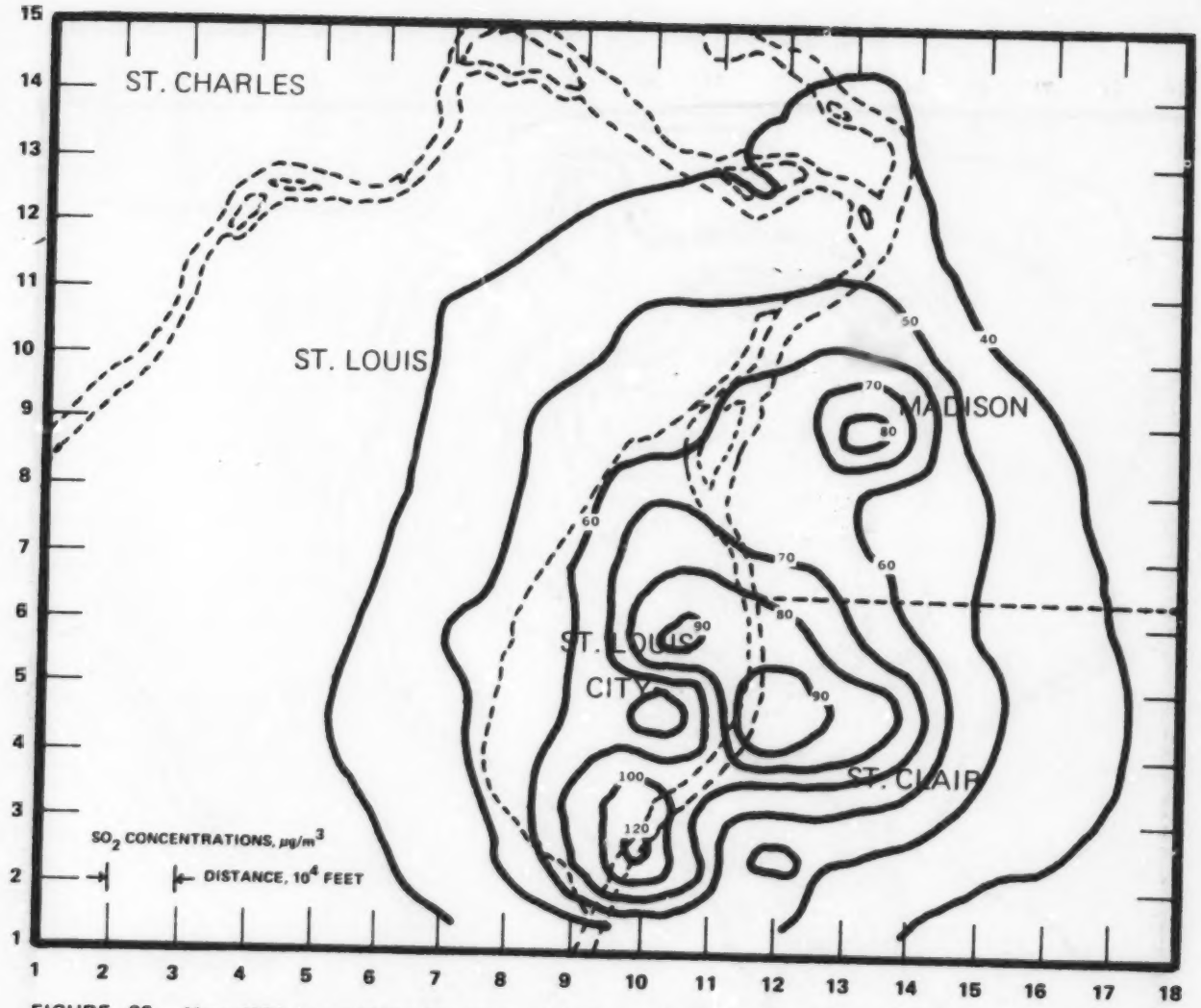


FIGURE 26 Mean 1990 Annual Sulfur Dioxide Levels in St. Louis Predicted by Model ($\mu g/m^3$).

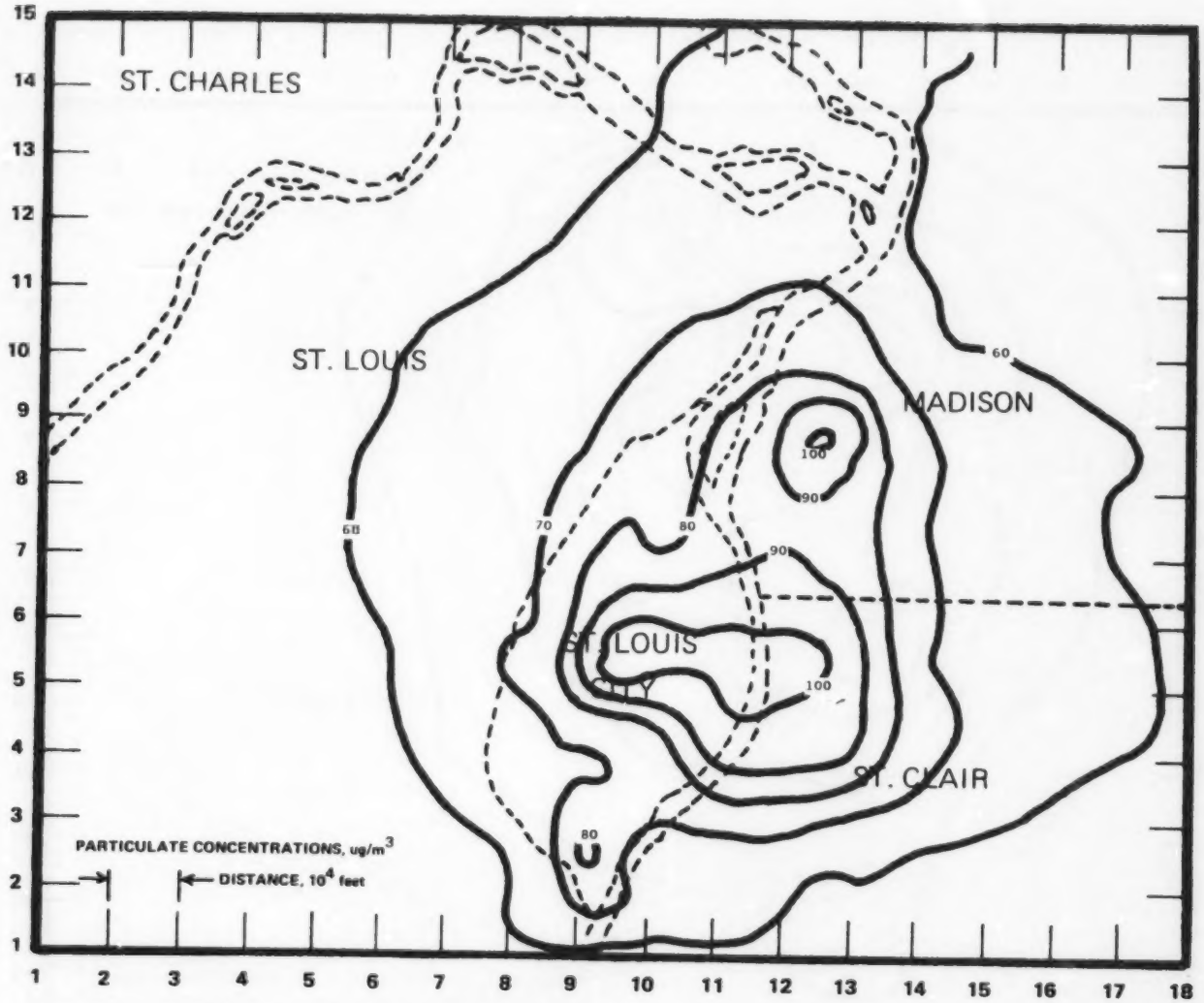


FIGURE 27 Mean Summer Suspended Particulate Levels in St. Louis Predicted by Model (ug/m^3).

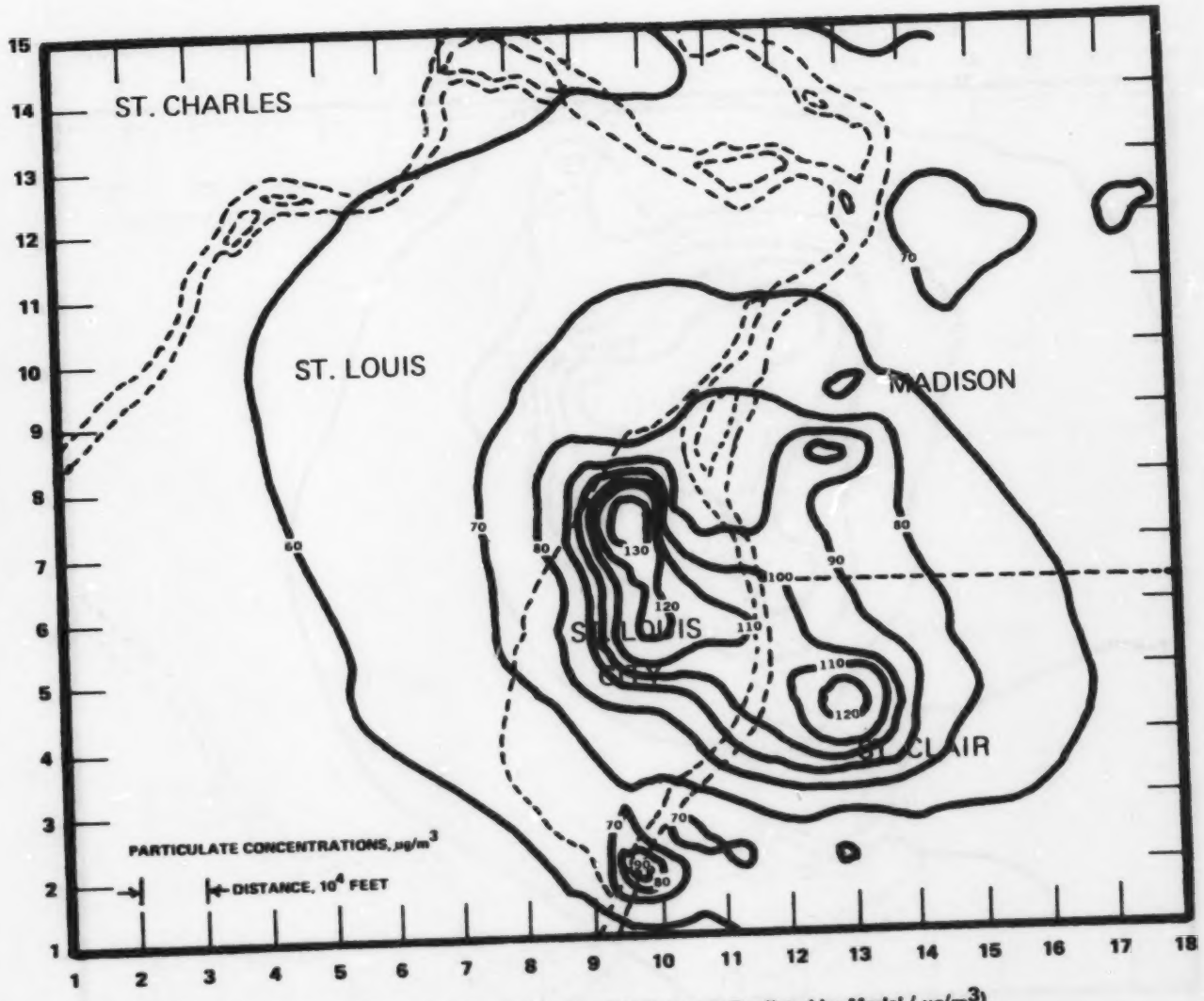


FIGURE 28 Mean Winter Suspended Particulate Levels in St. Louis Predicted by Model ($\mu g/m^3$).

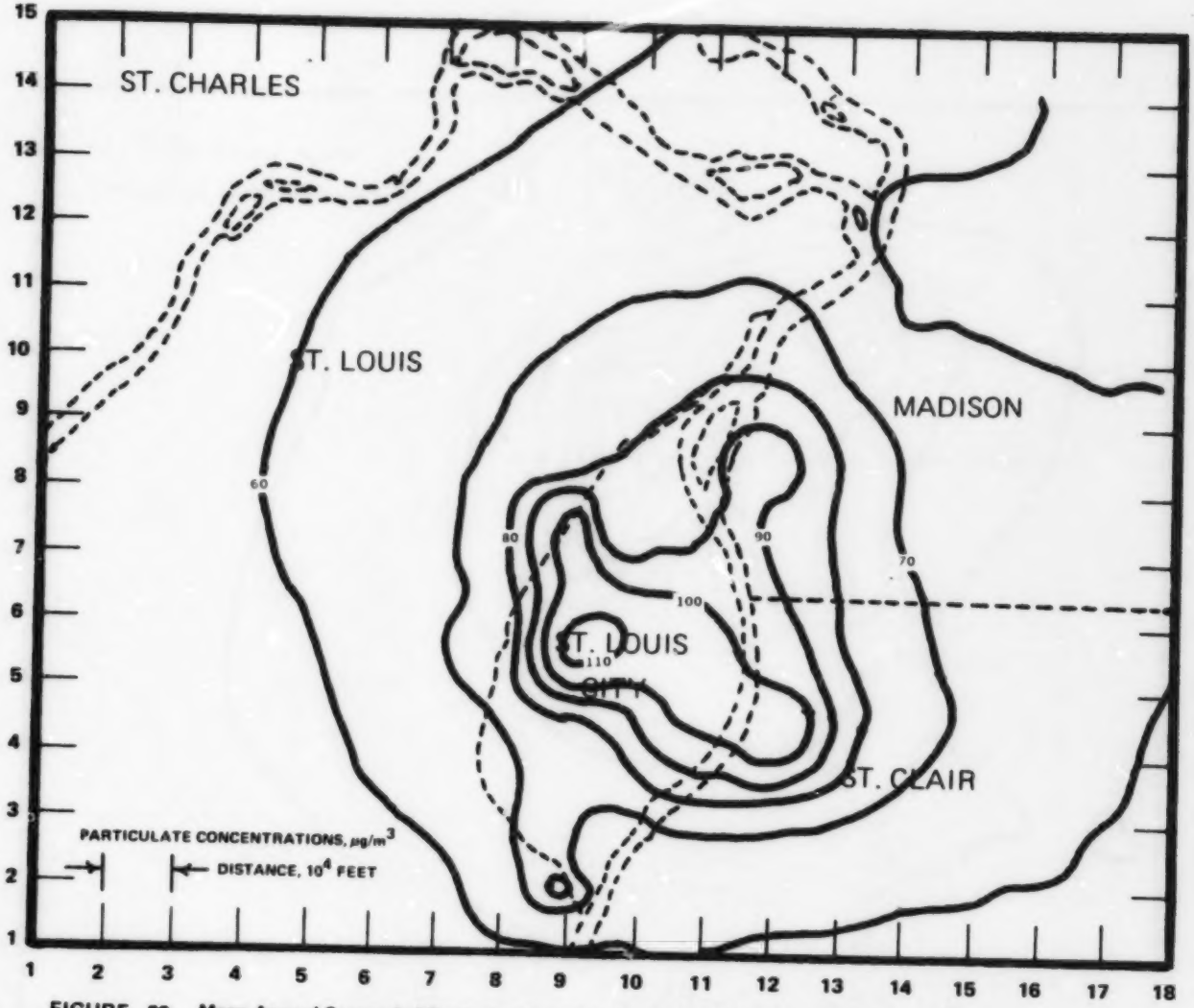


FIGURE 29 Mean Annual Suspended Particulate Levels in St. Louis Predicted by Model ($\mu g/m^3$).

Projections for annual 1990 (Figure 30) concentrations show a reduction over current values. Maximum annual levels are predicted to be 90 $\mu g/m^3$, and the areas affected by high concentrations to be reduced significantly.

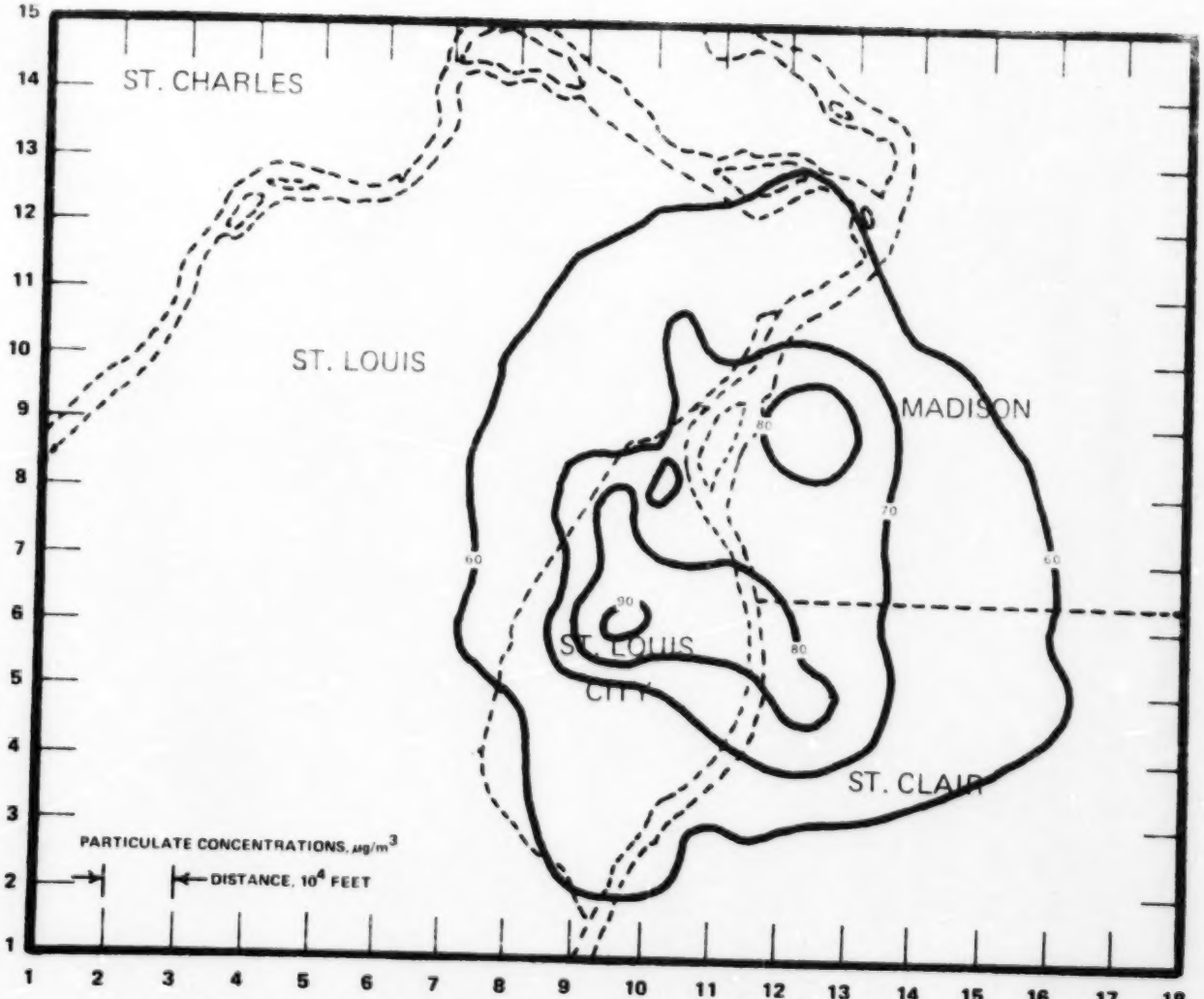


FIGURE 30 MEAN ANNUAL 1990 PARTICULATE LEVELS IN ST. LOUIS PREDICTED BY MODEL ($\mu g/m^3$).

REFERENCES

1. 1966 Interstate Air Pollution Study, Phase II, Project Report.

I. Introduction
II. Air Pollutant Emission Inventory
III. Air Quality Measurements
IV. Odors - Results of Surveys
V. Meteorology and Topography
VI. Effects of Air Pollution
VII. Opinion Surveys and Air Quality Statistical Relationships
VIII. Proposal for an Air Resource Management Program

2. McElroy, J. L. and Pooler, F., Jr., 1968, St. Louis Dispersion Study, Vol. I-II, U. S. Department of Health, Education, and Welfare, Washington, D. C.

3. Peterson, J. T., 1970, The Calculation of Sulfur Concentrations over a Metropolitan Area by Using Empirical Orthogonal Functions.

4. Pooler, F., Jr., 1966, A Tracer Study of Dispersion over a City, J. Air Pollution Control Assoc., 16, 677-681.

5. Turner, D. B., 1968, The Diurnal and Day-to-Day Variations of Fuel Usage for Space Heating in St. Louis, Missouri, Atmospheric Environment, 1968, Vol. 2, pp. 339-351.

6. Turner, D. B., 1969, Urban Atmospheric Dispersion Models--Past, Present and Future. Proceedings: Mid-Atlantic States Section, APCA Semi-Annual Technical Conference on What's in the Wind--Meteorological Aspects of Air Pollution Control, Drexel Activities Center, Drexel Institute of Technology, Philadelphia, Pennsylvania, March 21, 1969.

7. Calder, K. C., 1970, A Climatological Model for Multiple Source Urban Air Pollution, paper presented at the first meeting of NATO/CCMS Panel on Modeling, October 9, 1970, Frankfurt, Germany.

*U.S. GOVERNMENT PRINTING OFFICE:1973 514-154/251 1-3